# Anchor Bay Watershed Transition/Implementation Project

## Technical Report for Watershed Management Plan

**April 2006**
**Project No. G04211**

fishbeck, thompson, carr & huber
engineers • scientists • architects

# ANCHOR BAY WATERSHED

# TRANSITION/IMPLEMENTATION PROJECT

# TECHNICAL REPORT
# FOR
# WATERSHED MANAGEMENT PLAN

PREPARED FOR:
ST. CLAIR COUNTY HEALTH DEPARTMENT

APRIL 2006
PROJECT NO. G04211

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# TABLE OF CONTENTS



## LIST OF FIGURES

# TABLE OF CONTENTS



## LIST OF TABLES



## LIST OF APPENDICES

# INTRODUCTION

A large part of the Anchor Bay Watershed Management Plan update consisted of implementation tasks to provide technical support for the plan recommendations related to land use planning and zoning, storm water design criteria for new and re-developments, and a model storm water ordinance. This technical report is provided as a supplement to the Anchor Bay Watershed Management Plan and is organized as follows:

Chapters 1 through 3 describe the activities related to stream hydrology, hydraulics, and morphology including field work (survey and monitoring), analysis, evaluation, conclusions, and recommendations to maintain a stable system of streams. A flow chart of individual activities and their purpose is provided in Figure 0-1.

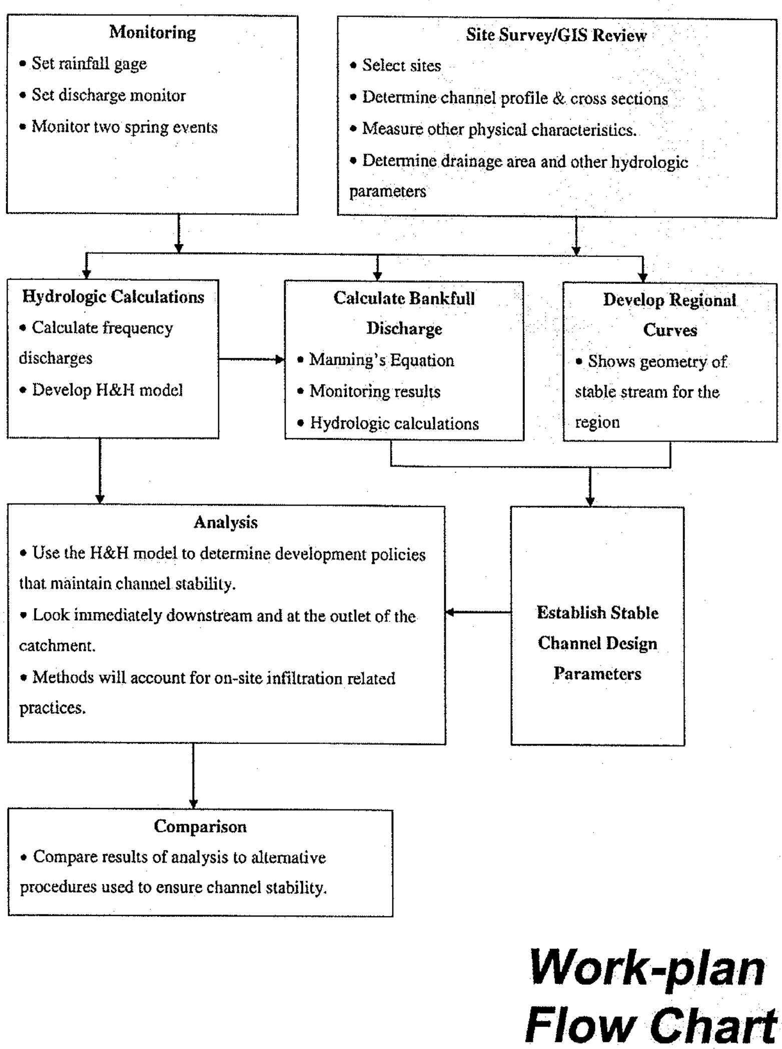



**Figure 0-1**

Chapter 4 describes the process used to perform the build out analysis, which can be used as the basis for watershed-based land-use decisions.

Chapter 5 explains the model storm water ordinance that incorporates the results of the previous chapters.

In summary, the recommendations resulting from this technical report will serve to:

- Protect headwater streams through storm water runoff flow rate and volume control and floodplain protection.
- Allow for more efficient designs of storm water controls that will provide adequate treatment without undue burden on developers by way of overly-conservative storage volume requirements.
- Provide a basis for requiring low impact development (LID) practices.
- Protect sensitive areas identified in the build out analysis to direct zoning decisions and impervious cover limits (if any).
- Achieve a cleaner Anchor Bay through reduced sediment loads and other nonpoint source pollution as a result of enactment and enforcement of the storm water ordinance.

# CHAPTER 1: REGIONAL CURVE DEVELOPMENT

## REFERENCE REACHES

Reference reaches were selected as a basis for the regional curves for the Anchor Bay Watershed included in Appendix 1. A total of 16 reference reaches located along 6 different water courses and distributed throughout the watershed were selected to represent typical stream types. Representative reaches were comprised of both natural and engineered (mechanically dredged) channels that had characteristics of a stable stream system. Stable reaches were determined to be those that did not exhibit excessive streambank erosion and had well-developed low-flow channels or floodplains. Channel morphology, geology, topographic relief, and vegetation remained fairly consistent throughout each study reach. Sites were selected beyond the influence of any hydraulic controls such as bridges, culverts, or weirs. Figure 1-1 shows a map of the Anchor Bay Watershed depicting the location of all 16 reference reaches.

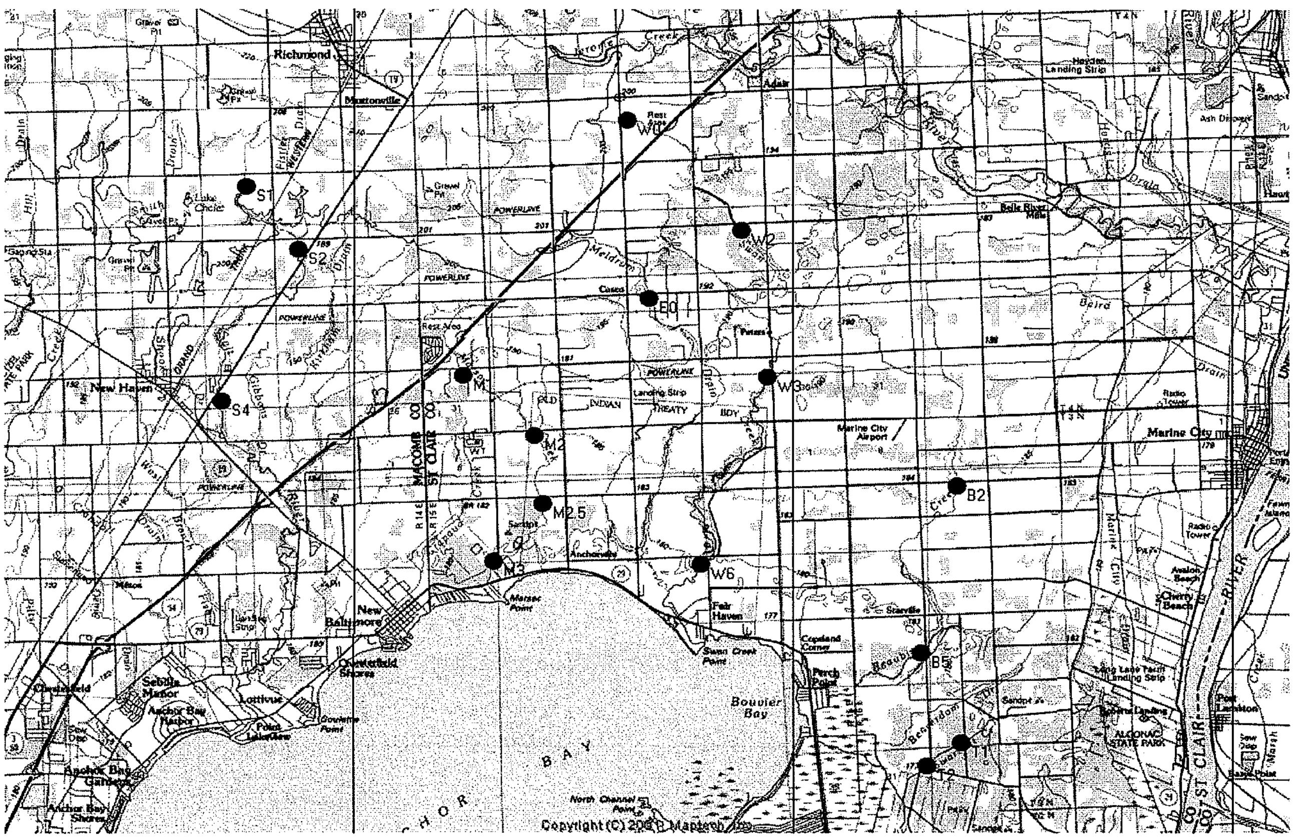



**Figure 1-1 Map Indicating Reference Reach Locations**

A summary of subwatershed areas and drain maintenance activities is indicated below in Table 1-1.

**Table 1-1 – Reference Reach Drainage Areas and Drain Maintenance Record**

| Water Course | Site ID | Drainage Area (Acres) | Date of Last Maintenance |
|---|---|---|---|
| Swartout Creek | T1 | 400 | 1950 |
| | T2 | 987 | 1950 |
| Meldrum Drain | E0 | 2,758 | 1959 |
| Swan Creek | W0 | 1,232 | Casco Drain - 1949 |
| | W2 | 3,018 | Casco Drain - 1949 |
| | W3 | 9,068 | Casco Drain - 1949 |
| | W6 | 11,210 | Not a County Drain |
| Marsac Creek | M1 | 1,179 | 1957 |
| | M2 | 2,643 | 1957 |
| | M2.5 | 4,709 | 1957 |
| | M3 | 5,264 | 1957 |
| Salt River | S1 | 1,334 | Richmond Drain - 1975 |
| | S2 | 2,212 | Not a County Drain |
| | S4 | 6,178 | Not a County Drain |
| Beaubien Creek | B2 | 3,756 | 1953 |
| | B5 | 8,643 | 1971 |

## LONGITUDINAL PROFILES

A field survey of the 16 reference reaches was conducted in November 2004. The elevations of the channel bottom, water surface, and bankfull heights were plotted over the entire length of each reference reach. Using least squares regression, a linear relationship was developed for the right and left bank, water surface, and channel bottom. The slope of the water surface elevation trend-line was then used to estimate the hydraulic slope of each channel reach. Survey data and longitudinal profile plots for each reference reach are included in Appendix 2.

The longitudinal profile for reference reach M3, located along Marsac Creek, downstream of the Bethuy Road crossing, is indicated in Figure 1-2. Notice the slight discrepancy between the left and right bankfull heights. In general, the larger of the two surveyed bankfull heights was used to calculate the bankfull depth of the channel. Also, the second and third (from the upstream end) bankfull estimates along the right bank were likely misread. Elimination of these two points has little effect on the trend line estimate.

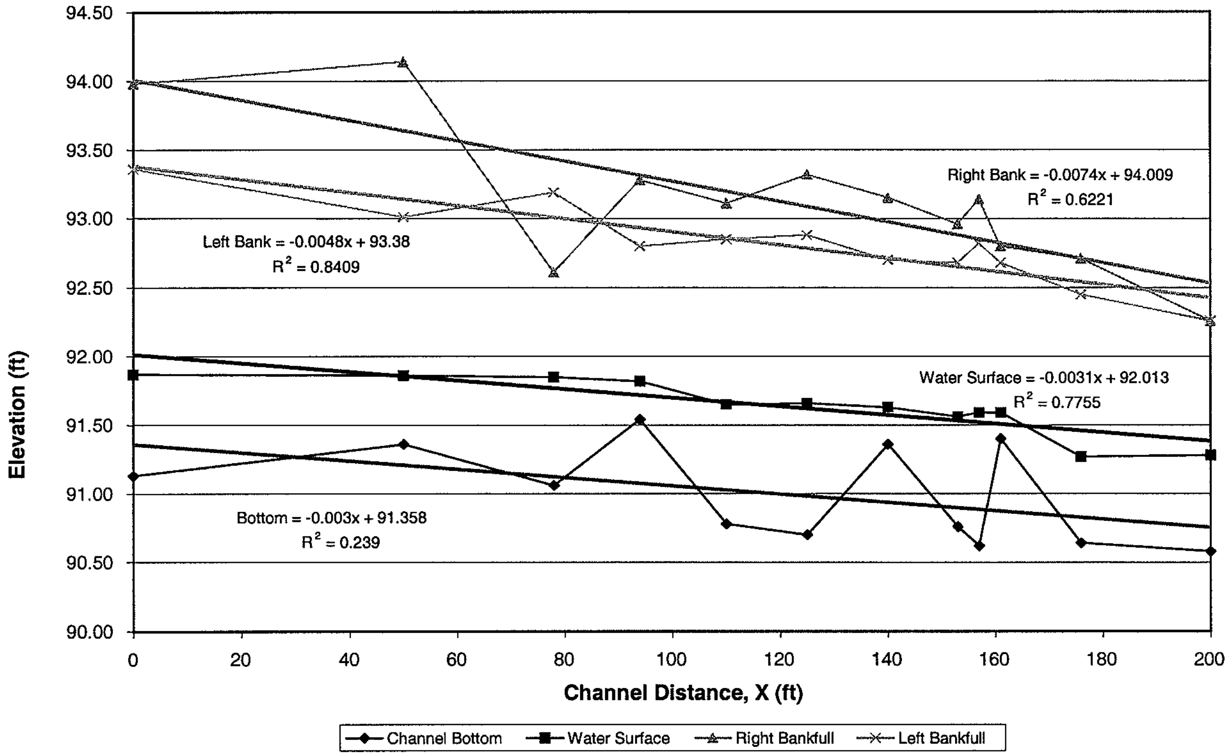



**Figure 1-2 Marsac Creek (M3) Reference Reach Profile**

## CROSS SECTIONS

A typical cross section of each reference reach was plotted to establish the bankfull cross sectional area, width, and mean depth. Cross section plots including tables of hydraulic parameters and bankfull elements are included in Appendix 3. Figure 1-3 shows a cross section of reference reach M3.

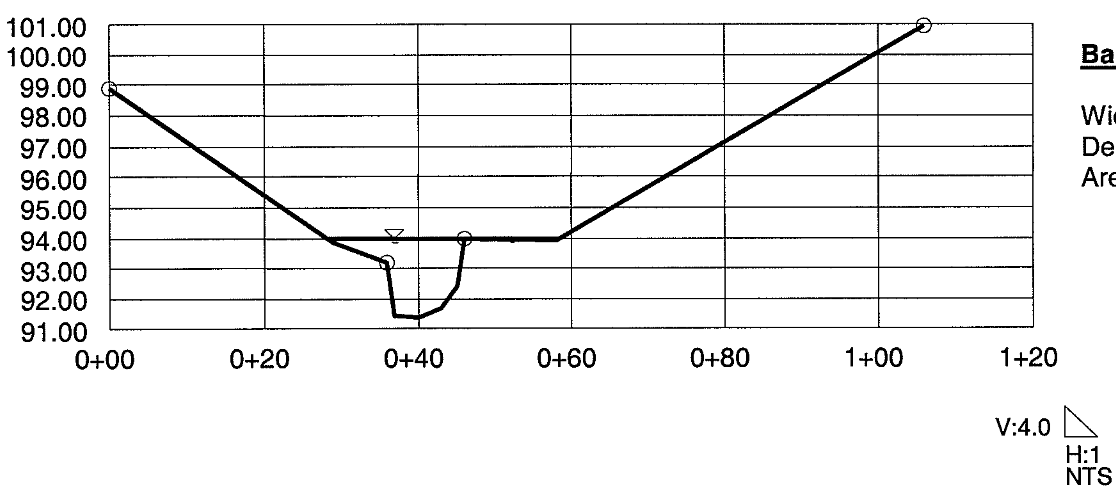



**Figure 1-3 Channel Cross Section for Reach M3**

Preliminary bankfull discharges for each reference reach were calculated using Mannings Equation and the FlowMaster computer program. Manning's coefficient (n) was determined by noting vegetative and streambed characteristics and comparing them to published values for other streams with known values of n. The bankfull area and hydraulic radius were computed using the typical reference reach cross section and bankfull depth. As stated previously, the hydraulic slope was based on the slope of the water surface elevation trend-line. Bankfull discharges were confirmed using the flow monitoring data collected during the spring of 2005. A comparison summary is included in Table 1-2.

**Table No. 1-2 – Comparison of Calculated and Measured Flow Rates**

| Location | Description | Calculated Bankfull Discharge (cfs) | Measured Bankfull Discharge (cfs) |
|---|---|---|---|
| S-1 | Salt River at 30 Mile Road | 8.6 | 7.3 |
| W-2 | Swan Creek at Lindsay Road | 12.0 | 9.3 |
| M-3 | Masac Creek at Bethay Road | 56.1 | — |

Output from the FlowMaster computer program for a typical cross section (located at Station 0+50) along reference reach M3 is summarized below.

| Project Description | |
|---|---|
| Worksheet | Marsac Creek (M3) - Sta. 0+50 X-Section (Pool) |
| Flow Element | Irregular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

| Section Data | |
|---|---|
| Manning's Coefficient | 0.032 |
| Channel Slope | 0.003100 ft/ft |
| Water Surface Elevation at station 0+50. | 94.00 ft |
| Elevation Range | 91.41 to 100.94 ft |
| Discharge | 56.11 cfs |

In order to correlate the bankfull discharge of each reference reach to an annual rainfall frequency, a logarithmic trend-line of the Michigan Department of Environmental Quality (MDEQ) discharge data was plotted using least squares regression. Discharge-frequency plots for each reference reach location are included in Appendix 4.

Figure 1-4 shows stream discharge plotted as a function of frequency (data provided by MDEQ) for reference reach M3. The equation for the curve is $Q=100.2\ ln(f)+73.78$, where $Q$ is the discharge in cubic feet per second (cfs) and $f$ is the return period in years. Therefore, the bankfull discharge (56.11 cfs) calculated for reference reach M3 occurs approximately every 0.8 year. (It should be noted that the highest frequency discharge provided by MDEQ was for a 1-year event. The results here use the MDEQ data to extrapolate outside the data range.)

All reference reaches have a bankfull discharge below the 2-year event (50% annual exceedance probability) with a majority of the bankfull discharges occurring at the 1-year event.

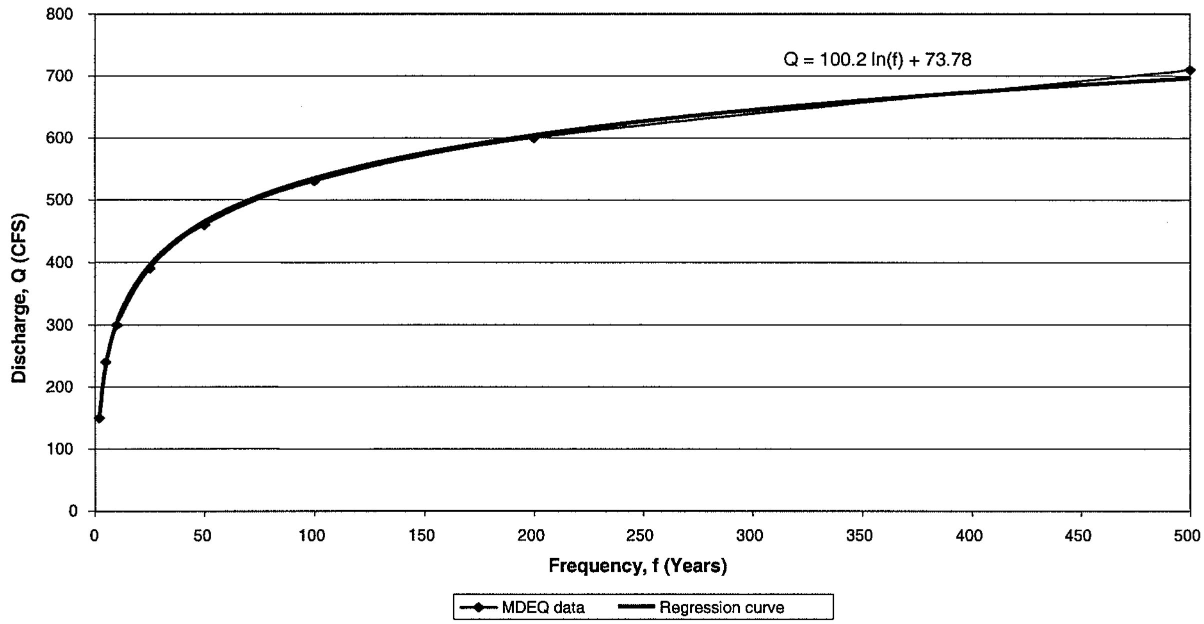



**Figure 1-4 Marsac Creek (M3) - MDEQ Discharge Data**

## PEBBLE COUNT

A cumulative particle size distribution curve of the pebble count data was plotted to characterize the channel bed material and to use as a cross-check of the measured bankfull depth. The mean grain diameter ($D_{50}$) was calculated and compared to the theoretical mean grain diameter ($D_{50}$) based on the 1x1=1 Rule (Ward and Allen, 2004). The 1x1=1 rule states that the diameter ($D_{50}$) of the bed material (inches) is equal to the product of the bankfull depth of flow (feet) and bed slope (%). Particle size distribution curves for each reference reach are included in Appendix 5 along with summary tables of general soil type and bed material analysis.

Figure 1-5 shows a cumulative particle size distribution curve of the pebble count performed along reference reach M3. The mean grain diameter ($D_{50}$) is approximately 9.65 millimeters (mm) or 0.380 inch (medium gravel).

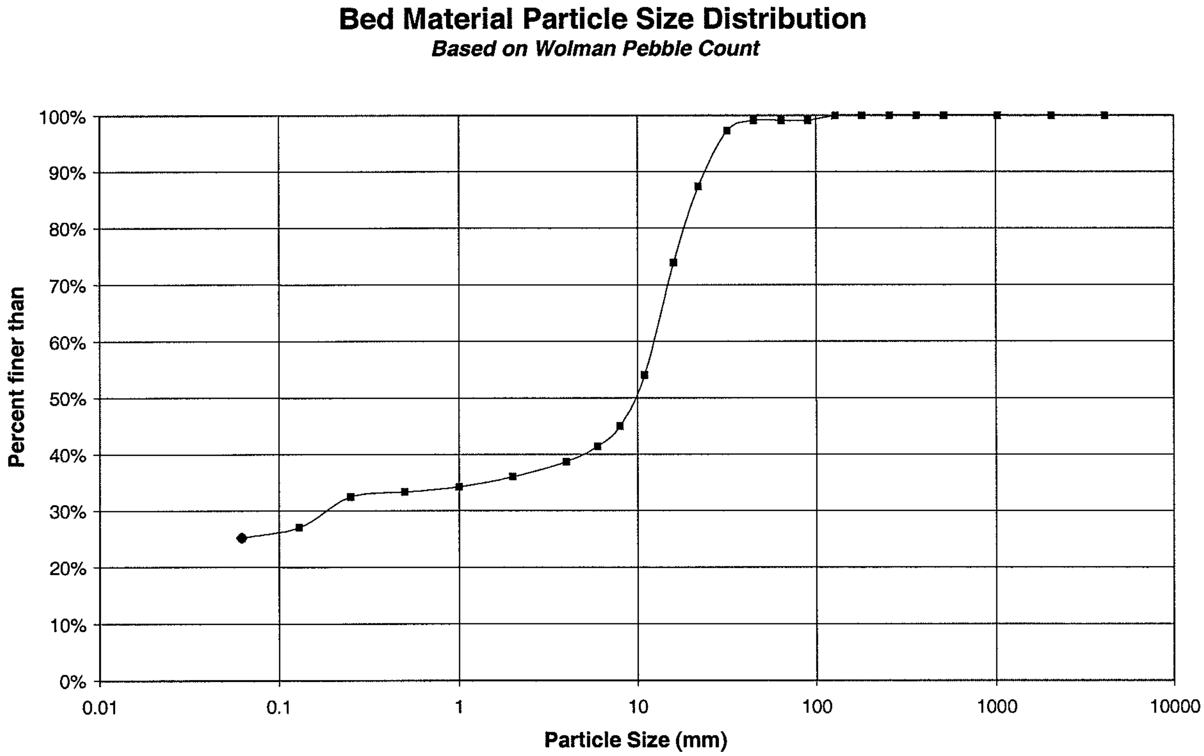



**Figure 1-5 Marsac Creek (M3) Pebble Count Results**

According to the 1x1=1 Rule, a 2.59-foot bankfull depth and 0.31% channel slope should yield a mean grain diameter ($D_{50}$) of approximately 0.803 inch (coarse gravel). This method is valid, assuming there is a well-graded soil stratum. However, in the case of the Anchor Bay Watershed, the prevailing soil type is that of a uniform, fine, clay loam. Therefore, the lack of larger sized grain material would result in a pebble count with a smaller bed size material than that predicted by the 1x1=1 rule.

## STREAM CLASSIFICATION

Each reference reach was classified based on its stream type as determined by the Rosgen Level II stream assessment method (Rosgen, 1996), which accounts for soil type, bed slope, entrenchment, channel width to depth ratio, and channel plan form. Data sheets for each reference reach and a summary of Rosgen stream types are included in Appendix 6.

Most reaches were classified as E6 with the exception of the furthest downstream reaches of the Salt River (S4) and Swan Creek (W-6), which were both classified as F6 due to a width to depth ratio greater than 12. Description of these stream types are included in Appendix 6.

## REGIONAL CURVES

Regional curves indicate the relationship between drainage area and stable cross-sectional channel geometry. Based upon the data collected from the November 2004 field survey, regional curves were developed for the Anchor Bay Watershed, relating bankfull cross-sectional area, width, and depth to drainage area. Due to the exceedingly high variability in measurements of bankfull height for reference reach M2.5, data from this reach was discarded. Again, using least squares regression, a linear relationship was developed to relate bankfull cross-sectional area, width, and depth to drainage area. The Coefficient of Determination ($R^2$) was calculated to assess the strength of each trend-line. $R^2$ may be interpreted as the fraction of the raw variation in y (bankfull dimension) accounted for using the fitted equation.

Figure 1-6 depicts the regional curves for the entire Anchor Bay Watershed using 13 data points from 5 different watercourses. (A full-page plot and a plot including the related data table are included in Appendix 1.) Data from reference reach M2.5 is excluded as stated previously. Reference reaches along Swartout Creek (T1 and T2) are also not included because bankfull indicators, such as natural forming low-flow channels or shoals, were not apparent. Furthermore, the sandy soils of Swartout Creek are inconsistent with the loam and clay soils dominant throughout much of the watershed. This can be seen in the General Soil Map from the *Soil Survey of St. Clair County*. The Wainola-Deford association (8) is the only association located within the watershed that is defined by sandy sub-soils.

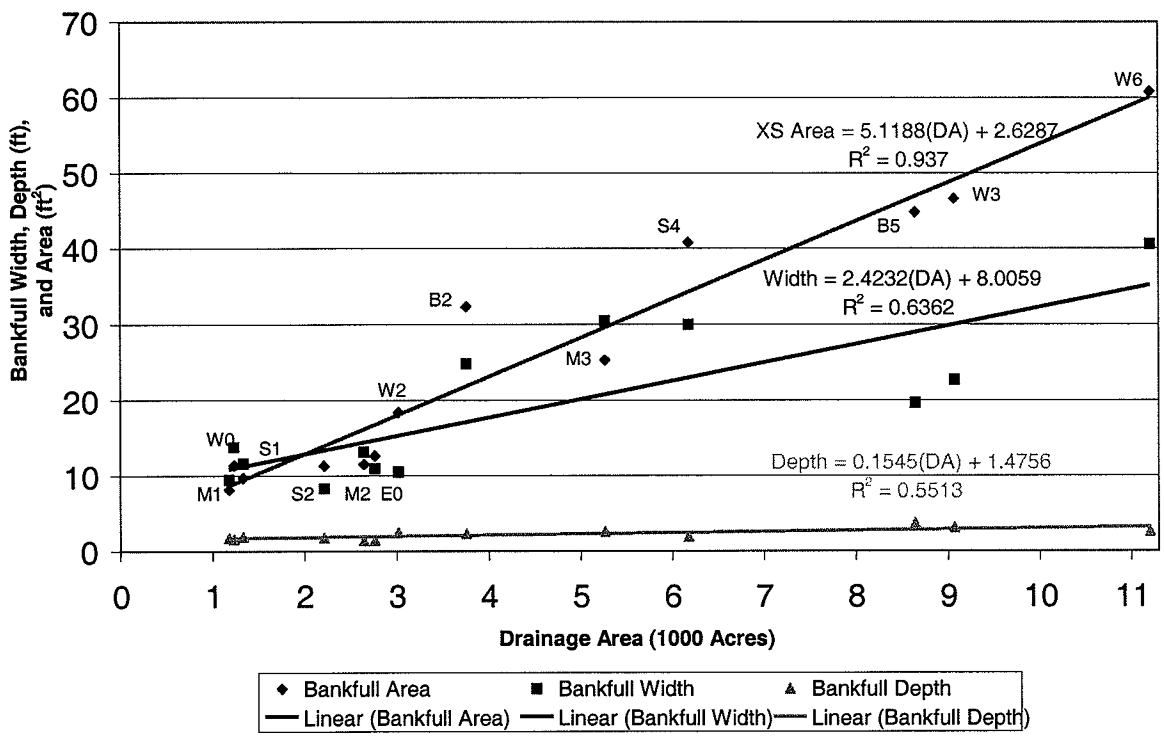



**Figure 1-6 Anchor Bay Watershed - Regional Curves**

An $R^2$ value of 0.937 indicates that nearly all of the variability in bankfull cross-sectional area is accounted for using the fitted equation, *XS Area = 5.1188(DA) + 2.6287*, where DA is the drainage area in thousands of acres. However, the relationship between bankfull width and depth to drainage area are not as strong, as indicated by the lower $R^2$ values.

As mentioned above, the Swartout Creek reference reaches, T1 and T2, have been excluded from the Anchor Bay Watershed regional curves due to their trapezoidal channel geometry and lack of bankfull indicators. The bankfull width and areas along Swartout Creek are considerably higher than other reference reaches with similar drainage areas. As depicted in Figure 1-7, the inclusion of reference reaches T1 and T2 significantly increases the theoretical bankfull area and width of watercourses within smaller drainage areas of approximately 1,000 acres and results in a lower $R^2$ value (0.8892).

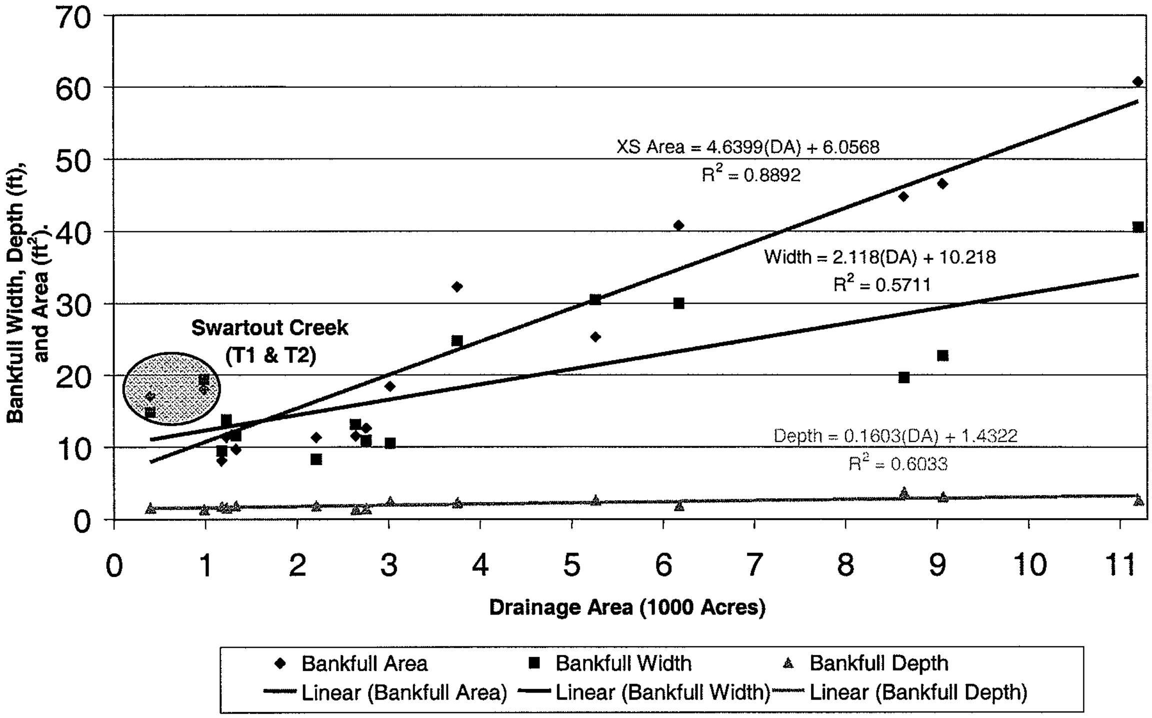



**Figure 1-7 Regional Curves with Swartout Creek Data**

## CONCLUSIONS

Based on the data collected from the field survey, a strong relationship exists between the drainage area and stable cross section channel geometry within the Anchor Bay Watershed. While bankfull width and depth generally increase with drainage area, their relationship is not as strong.

The bankfull indicators measured correspond to frequency discharges that occur an average every 0.8 year (10-month storm) as shown in Appendix 1. Monitoring results indicate that the measured bankfull discharge may not be the "effective" discharge associated with channel-forming flows as discussed in Chapter 2.

The regional curves developed from this study can be used to assess the condition of existing streams within the watershed, and appropriately size low-flow channels of multi-stage ditches proposed in conjunction with stream restoration or drain improvement projects. The regional curves, generated using 13 data points, should be used for the majority of the watershed, recognizing that variation (measured as an increase in bankfull channel width and cross-sectional area) may exist in the southeast region where soils are generally sandier.

The most stable stream sections identified for use as references reaches during this study are classified as an E6 stream type in upstream areas and on F6 stream type in downstream areas (within the influence of Anchor Bay) based on the Rosgen Level II stream assessment method.

# CHAPTER 2: RAINFALL AND STREAM MONITORING

## PURPOSE

Rainfall and stream monitoring was performed to support the regional curve analysis and the hydrologic modeling analysis. If one or more rainfall events occur that produce near bankfull flows, then the rainfall monitoring data can be used to determine the frequency of the bankfull event. Monitoring data from a larger rainfall event can also be used to calibrate the HEC-HMS hydrologic model used in the hydrologic analysis.

Steam gages and velocity measurements were also used to confirm hydraulic calculations performed using empirical equations that require assumptions regarding input parameters such as stream roughness (Manning's n).

## MONITORING DETAILS

Rain gages were placed at three locations in the Anchor Bay Watershed. Stream stage (water depth) gages were also placed at three (different) locations. Rating curves for these three stream gage locations were computed using stream flow measurements taken at each location on three different days.

The rain and stream stage gage locations are indicated in Figure 2-1. The rain gages were placed at the Richmond Wastewater Treatment Plant and at two rest areas along I-94 (one eastbound and one westbound). The three stream stage gages where placed on three of the reference reaches: Salt River downstream of 30 Mile Road (reach S1), Swan Creek downstream of Lindsey Road (reach W2), and Marsac Creek downstream of Bethuy Road (reach M3). Rainfall monitoring was performed between April 2 and May 23, 2005. A plot of the rainfall data as cumulative rainfall depth for each gage is included in Appendix 7. Stream gage monitoring was performed between March 28 and May 27, 2005. A plot of steam stage over the period of monitoring is included in Appendix 7. All stream stage and rainfall gages were placed and monitored by Mr. David Fongers (Michigan Department of Environmental Quality).

Since the stream stage gages only read the depth of flow in the stream, a rating curve was needed to compute the stream discharge during the period of observation. A rating curve is a plot of water depth shown as a function of discharge. Rating curves for all three of the monitored reference reaches are included in Appendix 8. The rating curves were determined by measuring the stream velocity on three different dates. This was done on March 28, May 14, and May 25, 2005. The stream velocity was measured using a Pygmy meter (see http://www.rickly.com/sgi/pygmy.htm for description). Discharge was then calculated using the cross-sectional area of the channel flow. Data sheets are included in Appendix 8.

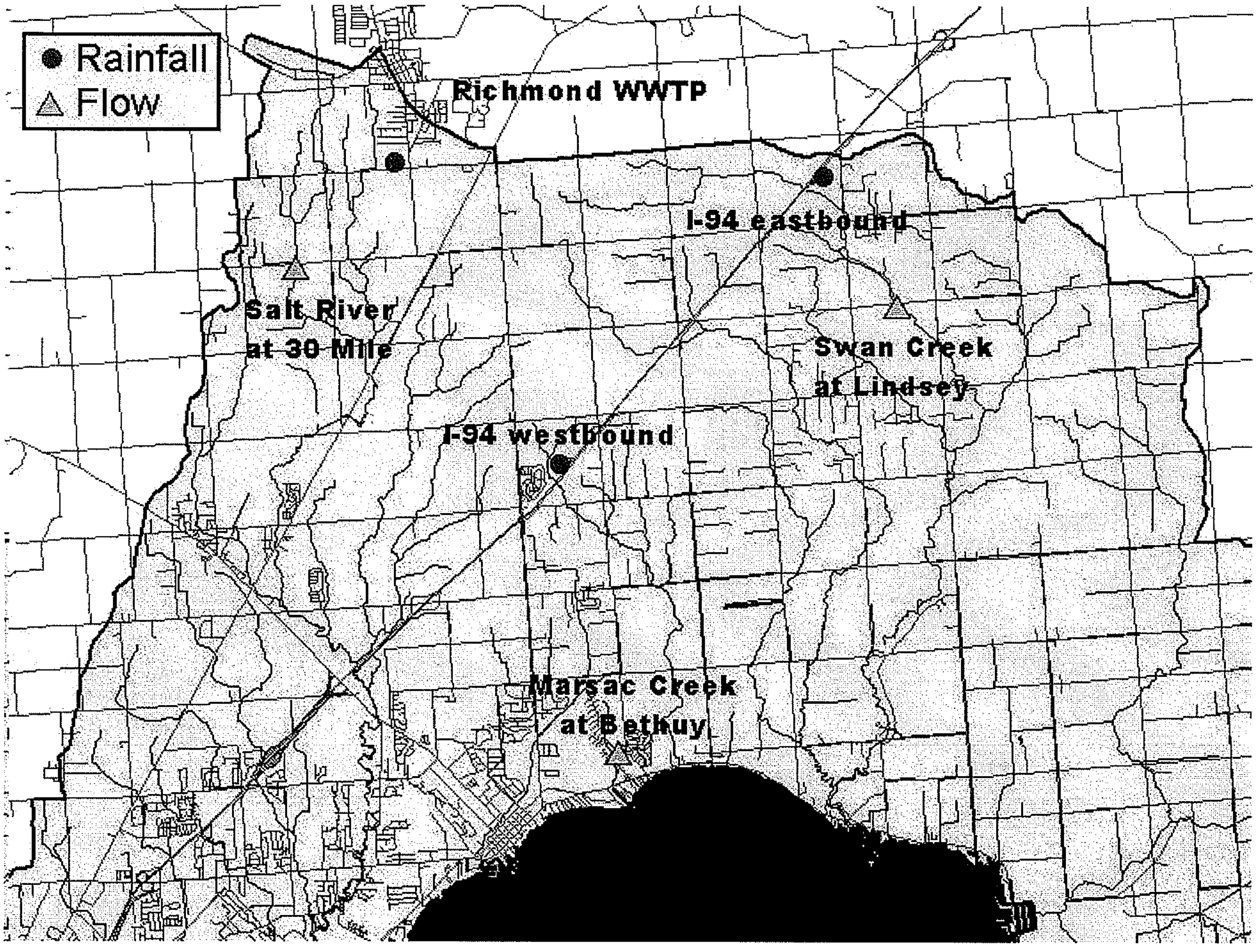



**Figure 2-1 Rain and Stream Gage Monitor Locations**

## RESULTS

During the monitoring period, there were no large, single-day rainfall events. The largest rainfall amount was recorded during a 5-day event that occurred between April 22 and 27, 2005. The three gages recorded between 1.8 and 2.3 inches during this period. The rainfall hyetographs at each gage are included in Appendix 7. Table 2-1 provides the results of the rainfall frequency analysis for this event.

The frequency analysis, indicated in Table 2-1, is done for each subwatershed (Salt River, Swan Creek, and Marsac Creek). A Thiessen polygon approach was used to determine which rain gages should be used for each monitoring location. Only Swan Creek is influenced by more than one rain gage. The frequency was determined by relating the measured 5-day rainfall to the rainfall-frequency data published for 5-day events in Illinois State Water Survey, Bulletin 71 (Huff & Angel, 1992). See Appendix 7.

Table 2-1 also compares the measured peak stage during this event to the bankfull stage (described in Chapter 1). It is very significant to note that bankfull flows were observed for very high frequency (commonly occurring) events. It should be noted that this analysis is for a 5-day event. Stream depths will be different for 24-hour events of the same frequency. The bankfull reported in the last column is based on a 24-hour rainfall event.

**Table 2-1 – Rainfall Frequency Results for 5-Day Rainfall Event**

| **Location** | Gage | Rainfall at gage [inches] | Percent of basin in gage zone | Total rainfall [inches] | Frequency [months] | Maximum recorded stream depth [feet] | Bankfull depth [feet] (Chapter 1) |
|---|---|---|---|---|---|---|---|
| Salt River | WWTP | 1.86 | 100% | 1.86 | 4.8 | 2.63 | 1.84 |
| Marsac Creek | I-94 West | 1.87 | 100% | 1.87 | 4.8 | 3.33 | 2.59 |
| Swan Creek | I-94 East | 2.25 | 85% | 2.19 | 7.7 | 3.78 | 2.47 |
| | WWTP | 1.86 | 15% | | | | |

The hydrologic model (described in more detail in Chapter 3) can also be used to estimate the bankfull frequency. The bankfull depth of 1.84 feet in Salt River is associated with a discharge of 7.9 cfs (based on rating curves). The (24-hour) rainfall depth in hydrologic model was varied until a discharge of 7.9 cfs was predicted. The frequency of the rainfall depth that produced 7.9 cfs was approximately 2 months.

## CONCLUSIONS

In the Anchor Bay Watershed, there appears to be a difference between an effective (channel forming) discharge normally considered to be a 1.5-year event (Rosgen, 1996) and the bankfull discharge as determined by existing bankfull indicators measured in the field. There are two possible explanations:

1. Recent development in the watershed has forced the (predevelopment) 1.5-year event to happen on a 2-month to 10-month frequency. This does not appear to be a reasonable explanation since the watershed is still predominately rural.

2. Channels were dredged 50 years ago and bankfull indicators are still building to a final equilibrium state. The loam clay soils which are present in the area deposit slowly. This is a more likely explanation.

It is important to note that in some reaches the bankfull indicators were the top-of-bank (this is not always the case) and discharges greater than the bankfull discharge utilize floodplain areas. If the effective channel-forming discharge is really on the order of a 1.5-year event, it is clear that this frequency of discharge makes use of the floodplain, which further reduces the impact to the channel. Therefore, if existing rural areas develop and floodplain fill is allowed (many of these low-lying areas are fields, not just wooded areas and wetlands), the result could mean an accelerated destabilization of the stream channel.

**Impact on hydrologic analysis**: There is not sufficient data nor reason to compel us to change stream protection criteria (discussed in Chapter 3) and base it on a 2-month frequency rainfall. Therefore, the 1.5-year criteria are still used as the basis for the hydrologic analysis. A comparison was made to determine the effectiveness of the criteria (based on a 1.5-year storm) during a 2-month storm. There was very little difference in methods tested for stream protection criteria.

# CHAPTER 3: HYDROLOGIC ANALYSIS

## OVERVIEW

The purpose of the hydrologic analysis was to determine the most effective detention policies to protect the Anchor Bay Watershed streams from development-induced streambank erosion. Streambank erosion can only occur when soil particles experience high enough shear stresses to become mobile. The shear stress is due to the component of the water's weight acting in a direction tangent to the stream channel (slightly downhill). As the depth of flow increases, so does the weight of water that has to be carried by the stream channel, and, subsequently, the shear stress increases. When the depth exceeds the bankfull depth, the over-bank areas are flooded and the weight of the water is distributed over a larger surface area. Using standard calculations, the average shear stress in a channel increases directly with the channel's hydraulic radius. The hydraulic radius is the stream channel's cross-sectional area divided by its wetted perimeter.

Stream change is also affected by the average stream velocity. With higher velocities, the soil particles that have become mobile are redeposited further downstream. Average stream velocities also increase directly with the channel's hydraulic radius.

The degree of stream change is also a function of the amount of time the soil experiences higher than normal shear stresses and velocities. If these high stress/velocity conditions occur infrequently or for short durations, then stream change is limited.

When development occurs in a watershed, the hydrology is changed in two ways. First, an increase in impervious cover results in a greater volume of runoff (less water infiltrates into the ground). Second, storm water conveyance (storm sewers and drainage ditches) reduces the time it takes for the runoff to reach the receiving stream. These two factors result in higher runoff rates (peak discharge) and higher runoff volumes. Current storm water detention policies address one of these issues. Detention ponds hold storm water and release it slowly. This reduces the peak discharge but does not reduce the volume, which is just as important.

Detention ponds can be designed for stream protection. One approach is to design the pond in such a way that the discharge results in no increase in the downstream bankfull flow rates. This maintains the shear stress and velocities at predevelopment magnitudes, but, since the volume of runoff has increased, the duration of these high shear stresses is much greater. Effective streambank protection requires detention releases that control both the magnitude and duration of the downstream shear stresses.

Evaluation of a typical subwatershed under various build out conditions and with four of the most common detention approaches to stream protection was performed to determine the effectiveness of each.

Alternative approaches using low-impact development techniques were then evaluated in light of the results.

## MODEL USE

The goal of the hydrologic model was to test out several detention policies to evaluate their impact on the receiving stream. Therefore, a numerical hydrologic model was developed for a small, mostly agricultural part of the Anchor Bay Watershed. The model was created with enough detail to allow modeling of changes made at the scale of a new residential or commercial development. The model was first developed and calibrated to give expected peak discharges under existing conditions. Three new versions were then developed. The first version assumed that one-third of the area was converted from agricultural use to residential and commercial use. The second and third versions assumed that two-thirds and finally all of the area were converted, respectively. Runoff from the newly developed areas in each of these models was then detained with a pond. The ponds were designed to operate under several release rate policies. The impact of the development and the trial policies on the receiving stream was then determined.

## WATERSHED SELECTION

The target was to have 20 to 40 sub-catchments, each with areas of 20 to 40 acres, at the scale of a typical development. This results in a modeled drainage area of somewhere between 400 and 1,600 acres. The discharge point of the model should correspond to one of the monitored reference reaches (described in Chapters 1 and 2). The model should also represent an area in the headwater range of one of the Anchor Bay streams.

The Salt River was selected for hydrologic modeling. The watershed is defined by a discharge point located where the Salt River crosses 30-Mile Road (reference reach S-1 as seen in Figure 1-1). The delineation of the contributing area was developed using U.S. Geological Survey (U.S.G.S) topographic maps. The contributing drainage area was determined to be 1,440 acres. Figure 3-1 indicates the 50 sub-catchments that were included in the hydrologic model. The sub-catchments were initially delineated based on the U.S.G.S. topographic map. They were then modified to correspond to the configuration of a typical development. The average size of each sub-catchment is 29 acres.


**Figure 3-1 Sub-catchments Used in Hydrologic Model**

## MODEL DEVELOPMENT

The computer program HEC-HMS was used to perform the hydrologic modeling. Soil Conservation Service (SCS) curve numbers were used to determine the runoff volumes. To be consistent with typical drainage response in Michigan, a Clark unit hydrograph was used with the time of concentration set equal to the storage coefficient to transform the runoff volume into a hydrograph. The modeled rainfall events follow an SCS Type II distribution.

**Sub-catchment hydrologic parameters**: The required hydrologic parameters for each sub-catchment are the drainage area, curve number, and time of concentration. Sub-catchment drainage areas were determined directly from the basin delineation drawing (done using Geographic Information System [GIS] software). For curve number calculations, seven land uses were identified from aerial photographs:

agricultural, low density residential, high density residential, commercial, open, forest, and water. Each sub-catchment was identified with either one or two hydrologic soil groups. Time-of-concentration was computed using the method outlined in *Computing Flood Discharges for Small Ungaged Watersheds* (Sorrell, 2003).

**Reach routing**: Reach routing was modeled using the lag method, based on assumed channel velocities and reach lengths.

**Calibration**: The model was calibrated to reproduce the estimated peak discharges provided at 30 Mile Road by the Michigan Department of Environmental Quality (MDEQ). The calibration process involved adjustments to the sub-catchment time-of-concentration. Monitoring data at reach S-1 were not available at the time of model development. After the monitoring data was available, it was used as a check of the validity the model. Predicted model peak discharge for the 5-day event (described in Chapter 2) was 16 cubic feet per second (cfs). The measured peak discharge was 14 cfs.

## MODELING DETENTION RULES

To model different detention/infiltration strategies, the watershed was "allowed" to develop in the model. Three different levels of development were modeled. At the first level, approximately one-third of the agricultural sub-catchments were converted to residential or commercial land uses. The second level converted another third. The final model assumed that all of the sub-catchments were converted. A sub-catchment was converted by adjusting both the curve number and time-of-concentration. The curve numbers were converted based on the assumed development type. The times-of-concentration were modified by converting all but 100 feet of sheet flow to waterway flow (reference Sorrell document). Table 3-1 provides details of changes that were made.

**Table 3-1 – Development Details for Modeled Subwatershed**

| | 1/3 build out | 2/3 build out | Full build out |
|---|---|---|---|
| Number of sub-catchments | 50 | 50 | 50 |
| Number of sub-catchments converted | 13 | 30 | 46 |
| Drainage area converted | 27% | 57% | 90% |
| Sub-catchments converted to low density residential | 6 | 12 | 21 |
| Area converted to low density residential | 11% | 21% | 40% |
| Sub-catchments converted to high density residential | 2 | 11 | 15 |
| Area converted to high density residential | 5% | 22% | 28% |
| Sub-catchments converted to commercial | 5 | 7 | 10 |
| Area converted to commercial | 11% | 14% | 22% |
| Estimated percent impervious for entire watershed | 16% | 27% | 40% |

In each of the development models described above, a detention pond was added downstream of each modified sub-catchment. All of the detention ponds were designed in such a way that they released the desired peak discharge at a depth of 3 feet. This depth was selected for the purpose of modeling only. It is simply a reasonable depth to detain a 1.5- to 2-year event. With a known peak pond depth of 3 feet, the size of the orifice outlet can be determined to give any specified peak discharge. The area of the pond was then adjusted to achieve the 3-foot depth. Four different release rate policies were tested.

**Constant release rate.** This method sets a specific value for the detention release rate for all new developments in the watershed. The value is given as a specified discharge per acre of developed area. The specified value can be established at diverse geographic scales. For example, a single release rate value can be mandated for a specific watershed, for a specific municipality, or for an entire county.

One method, applied at the watershed scale, uses the watershed yield as the prescribed detention basin release rate. The watershed yield is the peak, predevelopment watershed discharge divided by the watershed area. The MDEQ has suggested that this method be based on a 2-year rainfall event. Upstream of 30-Mile Road, the Salt River Watershed is primarily agricultural so the existing flows can be considered to represent predevelopment conditions. The 2-year peak discharge at this point (as determined by MDEQ) is 50 cfs. This results in a yield of 50 cfs per 1,440 acres or 0.035 cfs/acre. By comparison, the yield is 0.029 cfs/ac at the outlet for the entire 6,200 acres of the Salt River Watershed.

**Maryland.** The state of Maryland has established stream protection rules based on holding frequent events in storage for a specified amount of time. Instead of trying to match some post development condition to a predevelopment condition, this method is based on detaining the 1-year hydrograph for a 24-hour period. The 24-hour period is defined as the time difference between the centroids of the inflow and outflow detention basin hydrographs. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

This method is fundamentally different than the constant release rate approach because it incorporates information about the type of development. Specifically, hydrologic parameters associated with the developing area (i.e., time-of-concentration and Curve Number) are used to determine the desired release rate. The method is described in *Maryland Stormwater Design Manual* Appendix D.11 and is included with this report as Appendix 9. This method will be referred to as "Maryland."

**Impervious area release**. This method is currently used in Ottawa, Allegan, Montcalm, Mecosta, Oceana, Van Buren, and Newaygo Counties. Washtenaw County over estimates the storage volume required in a simplified version of this method. This method is similar to the Maryland approach in that it seeks to store and slowly release runoff from channel forming events. The computational basis for this method is that the runoff from a 1.5-year event should be held in storage for a 24-hour period. The method also assumes an "average" soil (i.e., a soil from a B/C Hydrologic Soil Group). Specifically, this method allows a peak detention basin discharge of 0.05 cfs per directly connected impervious acre in the development for a 1.5-year event and a storage volume of 5,000 cubic feet per impervious acre. These values were determined after making multiple runs for various impervious fractions using a detention basin routing program and then simplifying to a linear interpretation of the results. The method will be referred to as "Imp Area."

**Curve Number (CN) approach**. The last method to be tested is a variation of the Impervious Area method. It is currently being used in the Gun River Watershed in Allegan and Barry Counties. This method uses a peak discharge that is related to the developed Curve Number for parts of the site contributing to the detention basin. Although developed using rainfall amounts from Illinois State Water Survey, Bulletin 71 (Huff & Angel, 1992), Michigan Zone 8, this method was tested in the Anchor Bay Watershed which is located in Michigan Zone 7 and has slightly lower rainfall for a 1.5-year frequency event (2.0 inches in Zone 7 versus 2.2 inches in Zone 8). See Appendix 10 for full development details. This approach easily incorporates both pervious area soil types and the fraction of impervious area. The method also easily accounts for Low Impact Development (LID) techniques. The Curve Number is simply based on the part of the site actually contributing to the detention basin. For a 1.5-year event, the allowable release rates (cfs/acre) and detention volumes ($ft^3$/acre) are given in Figure 3-2.

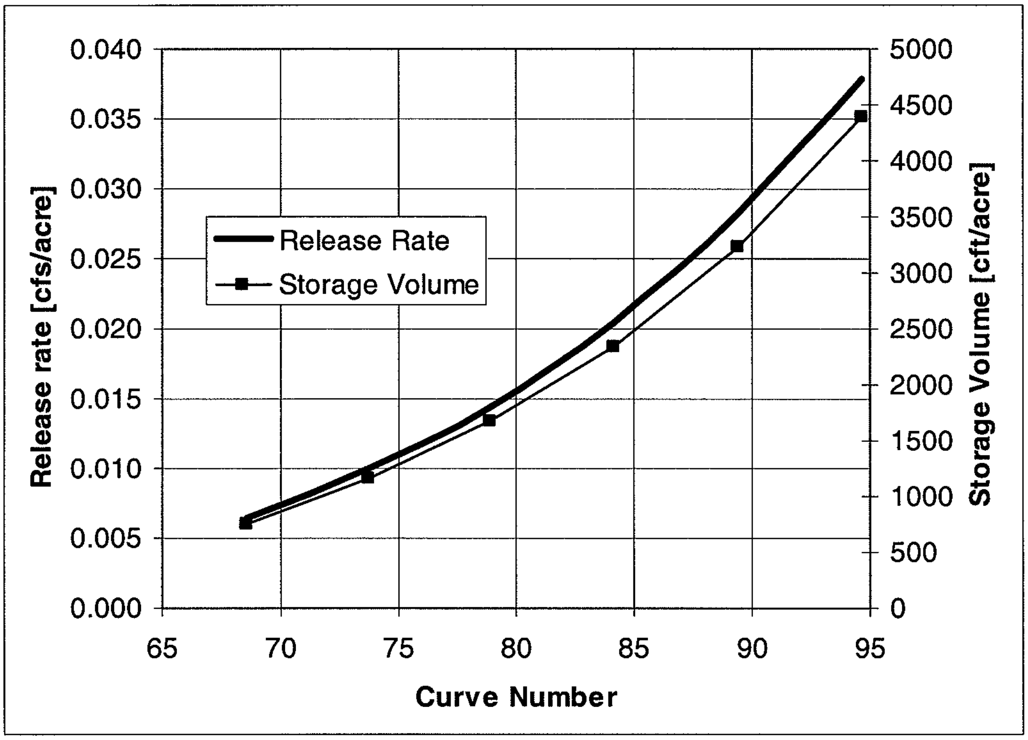



**Figure 3-2 Release Rates and Storage Volumes for CN Method**

The following equations can be used instead of Figure 3-2:

$$Q[cfs/acre] = 0.052\left(\frac{CN}{100}\right)^{5.47}$$

$$V[ft^3/acre] = 5960\left(\frac{CN}{100}\right)^{5.42}$$

This method will be referred to as the "CN" method.

For some sites where the weighted CN results in lower runoff volumes than considering the impervious area alone, the following minimum standards should be used:

$$Q[cfs/imp.area] = 0.052\left(\frac{98}{100}\right)^{5.47} = 0.05(DCIA)$$

$$V[ft^3/imp.area] = 5960\left(\frac{98}{100}\right)^{5.42} = 5340(DCIA)$$ (rounded to the nearest 10)

## RESULTS

Figures 3-3 and 3-4 show some of the results of modeling detention rules. Figure 3-3 compares the existing 1.5-year hydrograph to those after full development (all agricultural land converted to residential or commercial property) for each of the detention approaches described above. The Yield method works as expected—peak discharge matches before and after development with longer periods of near-bankfull flows. The other methods all reduce the peak discharge below that of the Yield method.

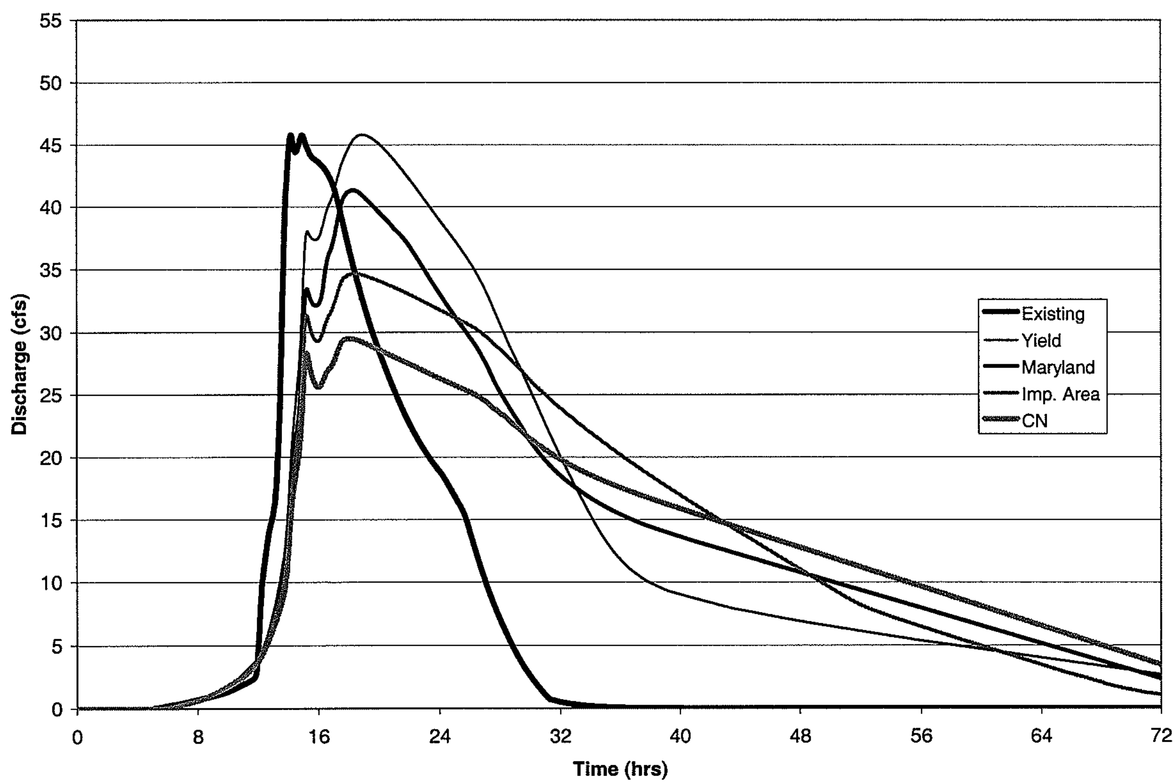



**Figure 3-3 Hydrograph Comparing All Methods at Full Build Out**

Figure 3-4 compares the existing 1.5-year hydrograph to those after three levels of development assuming that the CN method is applied. Note that at one-third development, the peak discharge is unchanged but the duration of high flows is actually reduced from the existing.

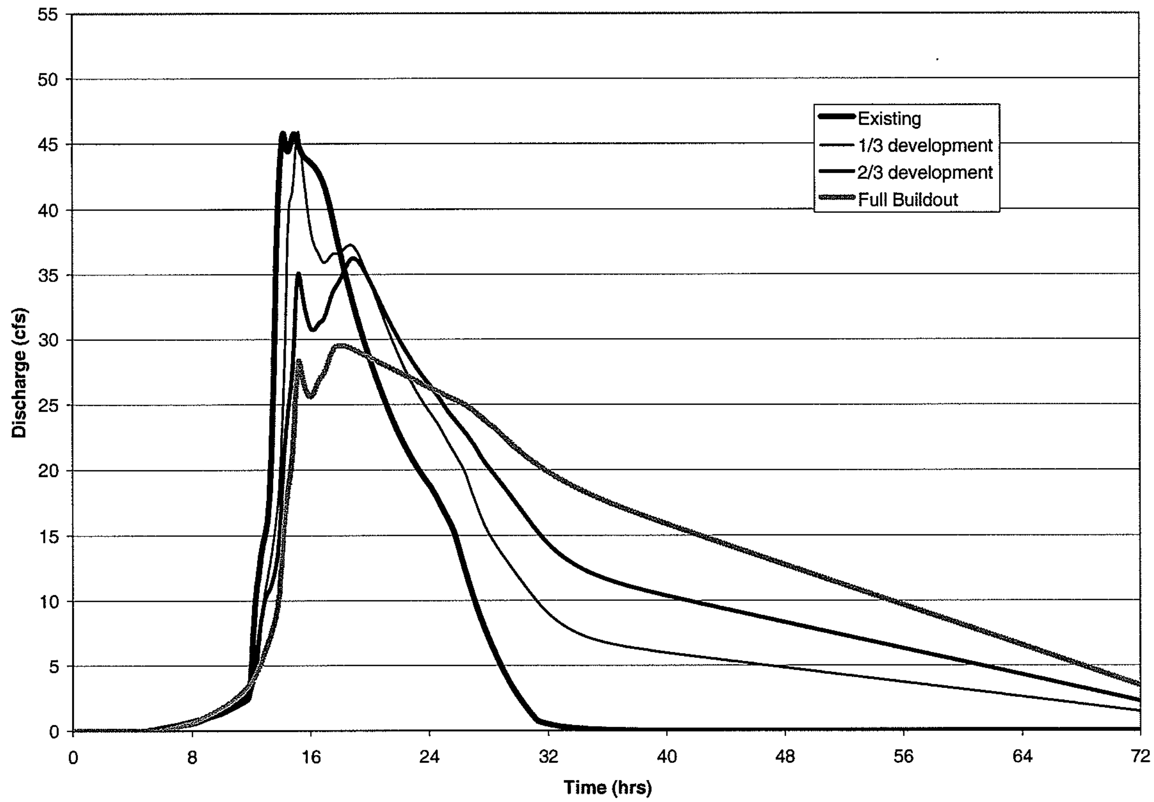



**Figure 3-4 Hydrograph Comparing CN Method at Three Levels of Build Out**

## MEASURING THE EFFECTIVENESS OF DETENTION RULES

The goal of this modeling is to determine the effectiveness of various streambank protection rules assuming only detention is being used to manage storm water. As mentioned earlier, the goal is to limit the frequency and duration of channel-forming flows. Several objective measures can be used to rate or score the performance of each approach. These methods all provide scores where a value of one indicates no change from the pre-development condition. A value greater than one indicates a negative impact of development, and a score less than one indicates a more stable stream. The results given in Table 3-1 are based on the response of the various detention models to a 1.5-year event.

- Peak Discharge score (PD). This is the peak discharge after development divided by the peak discharge before development. This method has been used frequently. It suffers from the flaw of not accounting for the duration of erosive flows just below the peak discharge.

- High discharge duration (HDD). This method recognizes that the duration of near channel forming flows is important. The measure is based on the duration of flows that produce a velocity in the stream channel equal to 75% of the stream channel velocity for the 1.5-year event. The score is this high velocity duration computed after development divided by the same value computed before development. While this method takes into account one additional factor (duration), it falls short in that an exceedingly high peak with a relatively short duration above the 75 percentile could receive a good score, while not actually being desirable. The search for a more adequate measuring index leads to the third method.

- Work Index (WI). The WI is a measure of the work done by erosive flows. This measure combines the effect of shear stresses, velocity, and flow durations. A high WI is a measure of the erosive energy of the stream. The method of computation is described in Appendix 11. The score is the WI after development divided by the WI before development. The critical hydraulic radius was selected to correspond to the 75% of bankfull velocity used in the HDD method. The WI was computed for the flows in the stream channel (not the over banks).

**Table 3-2 – Effectiveness of Detention Policies for Steam Protection**

| Level of Build Out | Detention Policy | Scoring for 1.5-Year Storm Event | | |
|---|---|---|---|---|
| | | PD | HDD | WI |
| 1/3 | Yield | 1.02 | 1.26 | 1.27 |
| | Maryland | 1.02 | 1.23 | 1.24 |
| | Imp Area | 1.01 | 1.30 | 1.19 |
| | CN | 1.00 | 1.23 | 1.10 |
| 2/3 | Yield | 1.02 | 1.44 | 1.63 |
| | Maryland | 0.98 | 1.54 | 1.38 |
| | Imp Area | 0.86 | 1.88 | 1.40 |
| | CN | 0.79 | 1.82 | 1.15 |
| Full | Yield | 1.00 | 1.63 | 1.88 |
| | Maryland | 0.90 | 2.41 | 1.64 |
| | Imp Area | 0.76 | 2.40 | 1.76 |
| | CN | 0.64 | 2.74 | 1.35 |

## CONCLUSIONS

As seen in Table 3-2, the CN method gives the most conservative results (work index nearest to one). It is also easy to apply by way of curve or formula.

These results indicate that the recommended criteria may not be wholly effective at full build out using detention alone (all WI values are greater than 1). Also, given the many variables and differences in predicted effective discharge versus measured bankfull discharge, a factor of safety is warranted. It appears that a more reliable way to ensure protection of stream channels is to reduce the volume of storm water runoff.

## RECOMMENDATIONS

Stream protection criteria based on the CN method is recommended for a storm water ordinance. This method is easily applied using curves or formulas. It should be noted that small developments and re-developments will not be able to implement stream protection through a standard detention basin if it results in an orifice that is too small. For soils in the Hydrologic Soil Group (HSG) categories A or B, stream protection volume must be provided other than through extended detention if the number of impervious acres in the development is less than two, and for soils in the HSG categories C or D, if the number of impervious acres in the development is less than one.

It is also recommended that a lower limit be imposed if the amount of runoff from the directly connected impervious area results in higher storage volume requirements than using the weighted CN number.

Figure 3-5 indicates the differences between recommended criteria that provide the highest level of stream protection using extended detention, and the Washtenaw County criteria (used in *Rules of the St. Clair County Drain Commissioner).* The Washtenaw County detention volume standard overestimates the required volume, because it assumes that all of the rainfall from the 1.5-year storm will be stored in the basin at one time. In reality, as the basin begins to fill, water will be immediately released, resulting in lower required detention volumes.

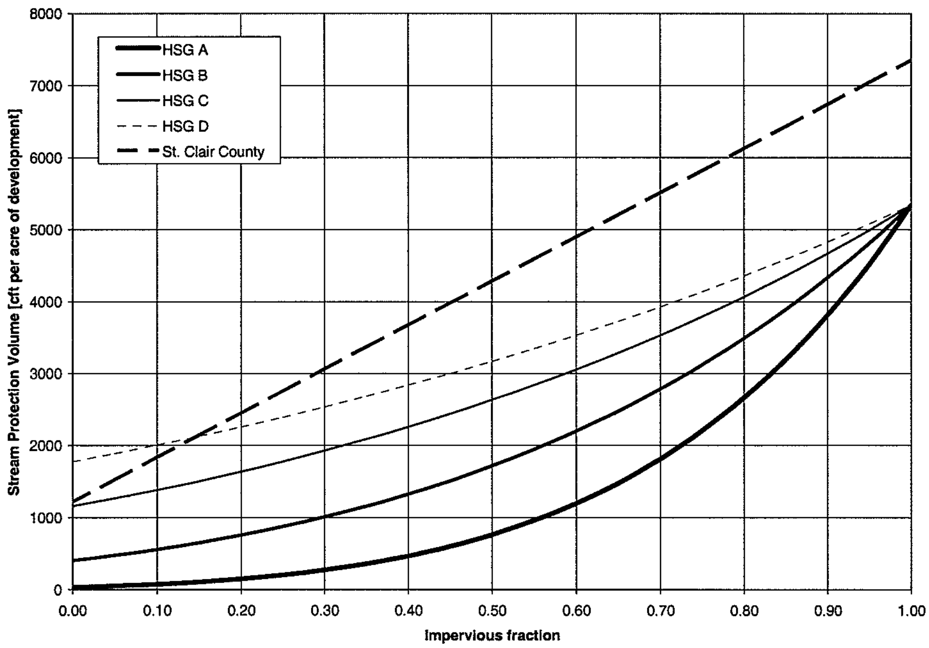



**Figure 3-5 Comparison of Existing St. Clair County Stream Protection Standard to Proposed**

The use of LID techniques for development site plans is recommended to avoid significant increases in runoff volumes which have as great or greater impact on stream stability as peak discharge rates. Only by addressing the volume of runoff will protection be provided for stream channels with a degree of certainty. Research (Schuler et al., 1998) has indicated that streams cannot be maintained in their natural state, becoming impacted and degraded at levels of impervious greater than 10%, even with traditional best management practices (i.e., detention) in place. Although the detention criteria recommended above will provide for the best protection of water resources and surface improvements that detention alone can provide, it still may not achieve a build out condition with "no negative impact."

It is also recommended that floodplain regulations be enforced and include protection of floodplains for drainage areas of less than 2 square miles. This is important because the floodplains are currently being used during effective discharge events in many of the streams. If these are encroached upon, negative impacts to the morphology of the channel (meandering, down cutting, bank erosion, and subsequent deposition) will most likely be induced.

The drafted ordinance for flood control detention storage volume is based on controlling flows from a 100-year storm. We recommend considering a change to a 25-year storm as is the case in other Michigan communities. The 100-year event, which is the standard for the federal flood insurance program and is used by the Michigan Department of Transportation (MDOT) as the basis for establishing the design of bridges, may be too stringent for a storm water management master plan. Because it is such an extreme event, the 100-year flood usually cannot be managed with traditional urban runoff controls. A more optimal balance between economy and flood protection may be realized by designing flood protection and a 25-year recurrence interval (Camp Dresser & McKee, 1991). Based upon a U.S. Army Corps of Engineers study of nationwide flood damage data complied by Federal Insurance Administration (FIA), additional justification for selecting the 25-year flood event is now provided. The significance of different flood return periods was evaluated using generalized relationships between flood depth and damages for different types of property and generalized elevation-frequency relationships for different severities of flood hazard (Johnson, 1985). This study concluded that the average annual flood damages within the 25-year floodplain are very high, up to ten times greater than the damages associated with the incremental area between the 25-year and 100-year floodplains. This conclusion suggests that a 25-year design event is a reasonable upper limit for storm water management design criteria. However, changing the ordinance to a 25-year event should only be done after further study to ensure that the predicted 100-year floodplains will remain with current levels with detention criteria based on a 25-year recurrence interval.

The *Rules of the St. Clair County Drain Commissioner* also define water quality volume as the first 0.5 inch of rain that must be treated. This rainfall amount is multiplied by the Rational Formula runoff coefficient to compute a final treatment volume for the site. Recommended allowable treatment should include:

- Permanent pool
- Extended detention (volume released over 24 hours)
- Infiltration
- Other treatment device (filter, vegetation, swirl concentrator)

Figure 3-6 compares the recommended water quality volumes, stream protection volumes, and flood control volumes. It also compares flood control volumes for both the 25-year and 100-year (current standard) events.

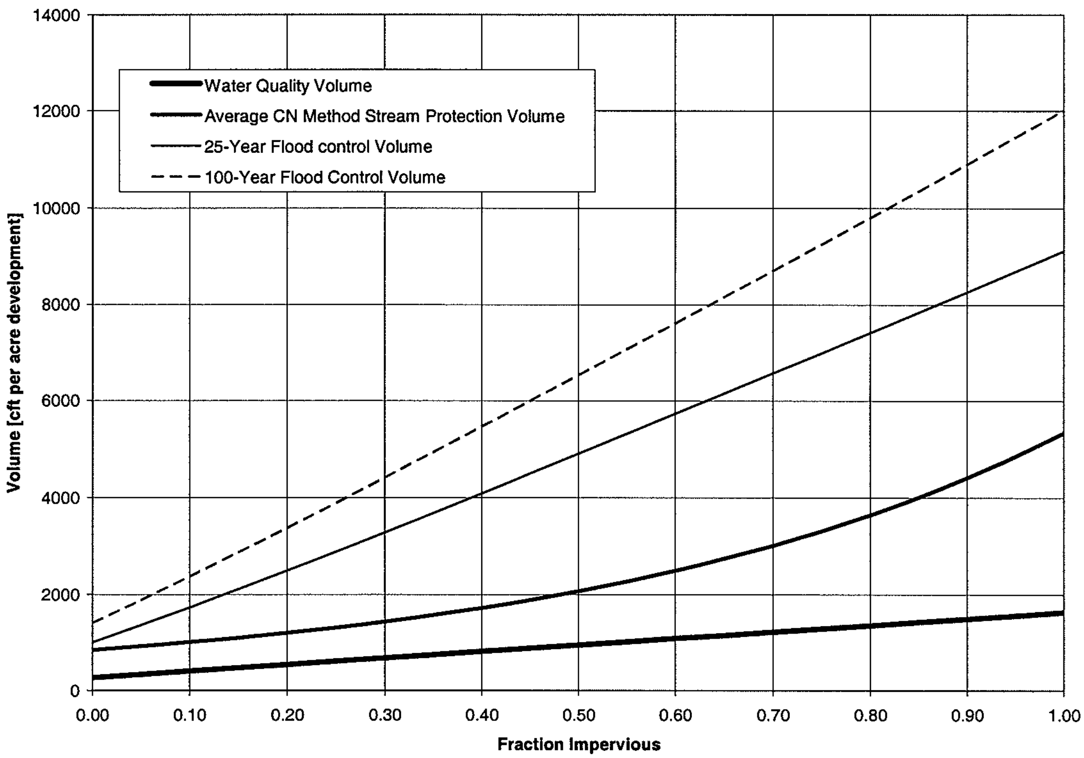



**Figure 3-6 Comparison of Proposed Detention Volumes**

# CHAPTER 4: BUILD OUT ANALYSIS

## INTRODUCTION

Land use planners interested in preventing and/or mitigating the impacts of urbanization on water resources need to be aware of the extent of impervious surfaces in their community and ways to use this information for better community planning and site design. The relationship of impervious surface cover to water quality and quantity can be used on large and small areas, even if specific pollutants and sources are not identified. Impervious surfaces can be measured and documented; they are easily recognized by the public in the landscape. Impervious surface is a practical planning tool for reviewing existing land use and the potential effects of future development on water quality, because it can be easily seen and measured. It allows for a variety of future land use scenarios to be reviewed and compared, thus supporting the decision-making processes of planning and enforcement of zoning, subdivision, and wetland regulations.

The conversion of pervious surfaces such as farmland, forests, wetlands, and meadows into impervious surfaces such as rooftops, roads, and parking lots increases surface runoff during storm events. This increase in runoff affects the hydrology, morphology, water quality, and ecology of surface waters in a watershed. Past studies have resulted in a current understanding of how the level of imperviousness in a watershed can be linked to stream degradation. As little as 10% watershed impervious cover has been linked to stream degradation in many regions of the county.

Current impervious cover, estimated from satellite imagery, can be contrasted with projected levels of imperviousness derived from a zoning-based build out analysis. The build out analysis allows township officials to visualize a possible future of their community, not in the conventional terms of populations or buildings, but in terms of impervious cover, and, by inference, the health of local water resources.

The Anchor Bay Watershed (Watershed) Transition project used Environmental Systems Research Institute (ESRI) ArcView 8.3, ESRI Spatial Analyst 8.3, and National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center Impervious Surface Tool (ISAT) software to analyze existing and potential impervious surfaces at build out within the Watershed. ISAT is an extension for ArcView and is available for ArcView versions 3.x and 8.x.

NOAA states that ISAT was developed to help managers and planners make a determination about the impact of impervious surface coverage on local water quality. ISAT applies impervious surface coefficients to a remotely sensed land cover data grid to determine the total and the percentage of impervious surface within a given area. In the Watershed, this tool was also used to determine the effects of impending land cover change on impervious surface. The tool is available free of charge from the NOAA Coastal Services website: http://www.csc.noaa.gov/crs/cwq/isat.html (Figure 4-1).

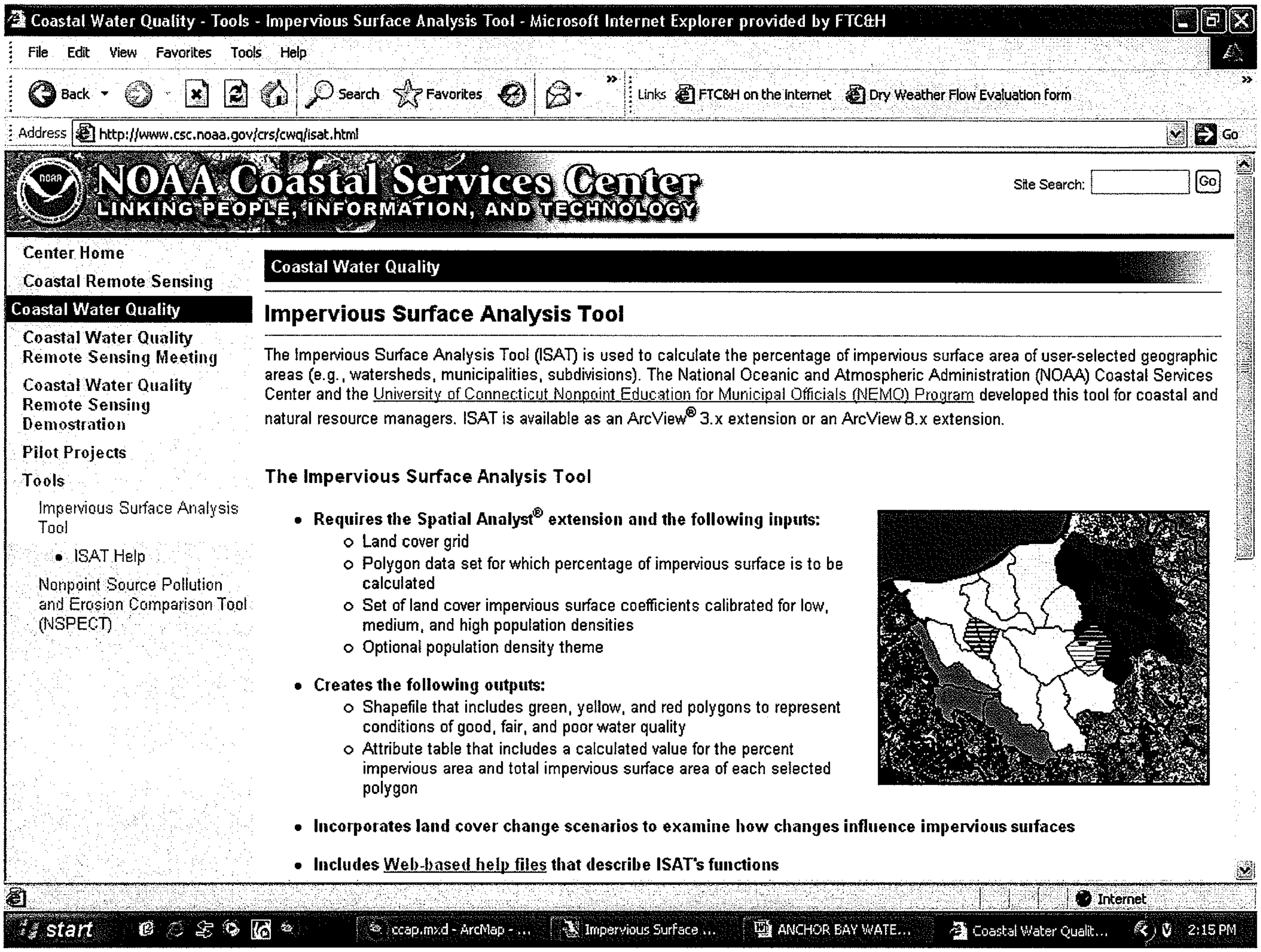



**Figure 4-1 – NOAA Coastal Services Center**

## PART ONE - DATA COLLECTION

### Base Map and Watershed Delineation

Base map and watershed delineation files were collected for the entire Watershed. The Watershed encompasses areas in St. Clair and Macomb Counties. The Center for Geographic Information (CGI) Framework was selected for base mapping of roads, surface water, county, and municipal boundaries. This data is provided in ArcView shape file format and is available for download at the Michigan Geographic Library website: http://www.michigan.gov/cgi.

The watershed delineation for the Watershed (red) was provided by St. Clair County and Macomb County GIS (Figure 4-2).

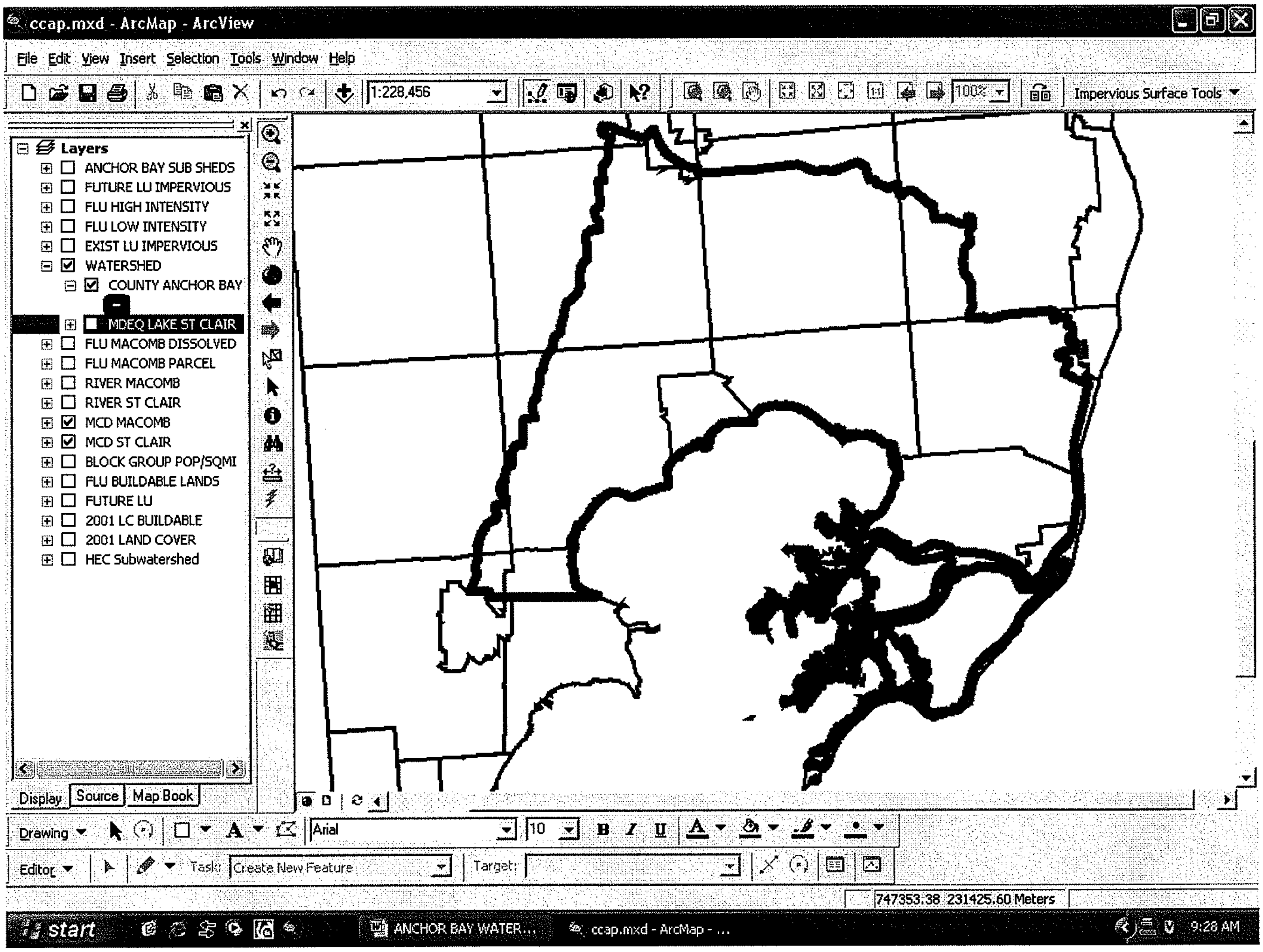



**Figure 4-2 – County Watershed Delineation**

Watershed delineations for the Watershed as provided by the Michigan Department of Environmental Quality (MDEQ) are also available from the CGI. The Watershed "MDEQ LAKE ST. CLAIR DELINEATION" (green) differs from the county definition (Figure 4-3). The county delineation removes part of Harrison Township and all of Marine City from MDEQ watershed delineation. The county delineation also adds island lands in Clay Township to MDEQ watershed delineation. The county delineation, however, does not include subwatershed boundaries which are provided by MDEQ.

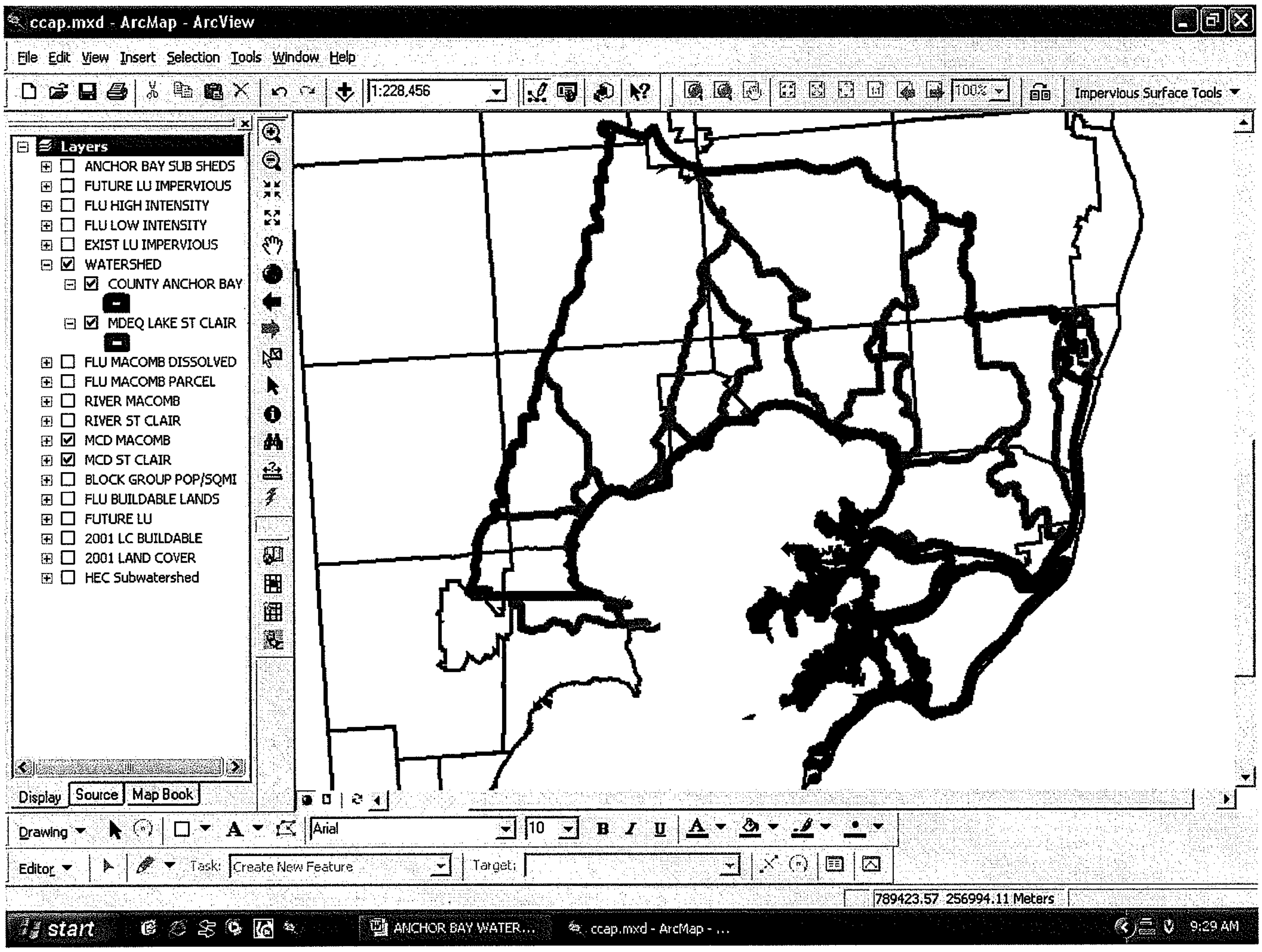



**Figure 4-3 – MDEQ Watershed Delineation**

A union of the county watershed delineation with the MDEQ Lake St. Clair subwatershed delineations was performed using the ArcView Geo-processing wizard. Upon completion, the file was cleaned to remove slivers and overlaps. The result is stored in the Anchor Bay Subwatersheds layer (orange) (Figure 4-4).

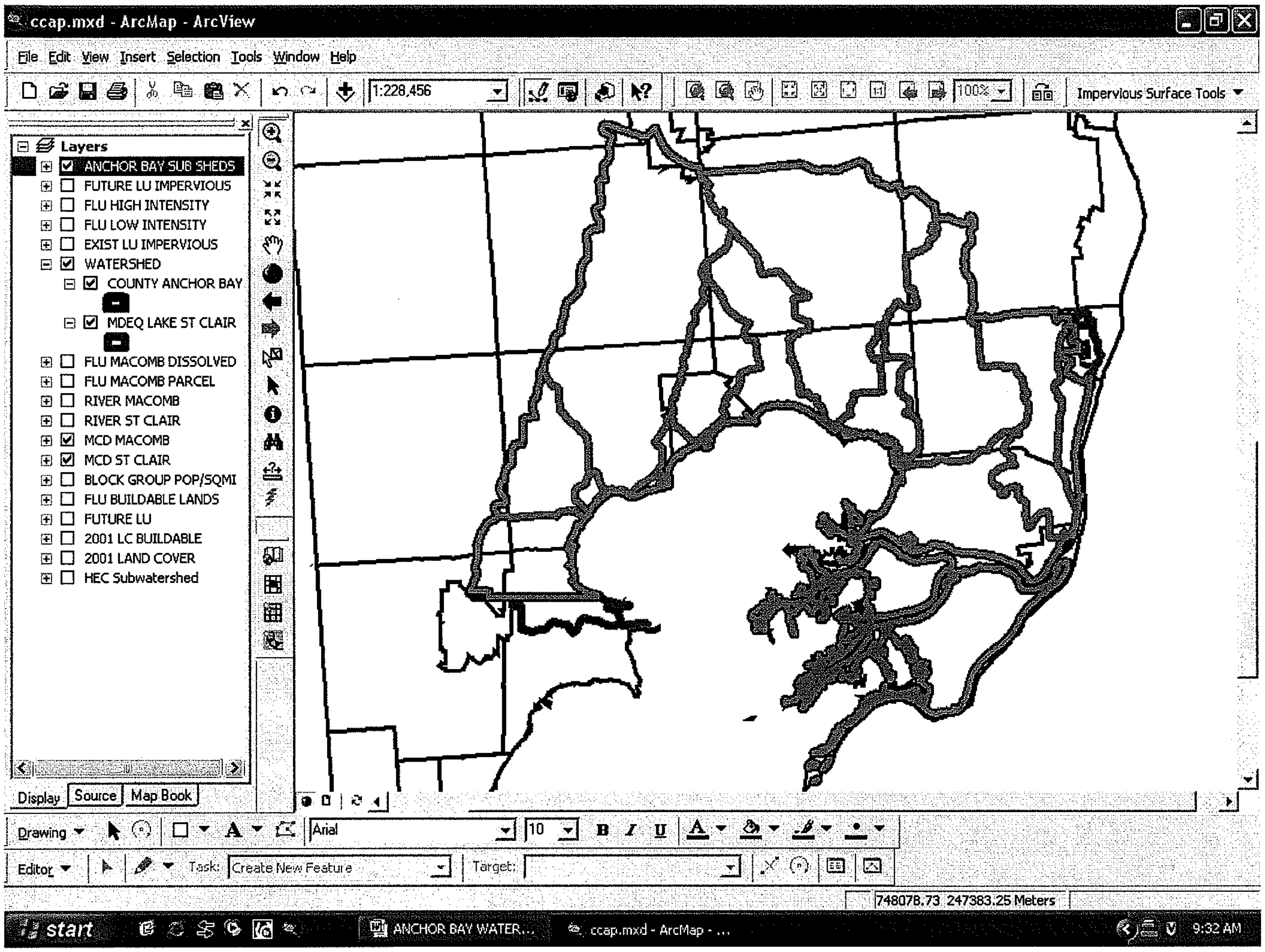



**Figure 4-4 – Watershed Delineation Union**

The resulting subwatersheds are numbered based on MDEQ subwatershed identification codes. Subwatersheds which were added by St. Clair County GIS to include islands in Clay Township do not have a unique identification number and are thus labeled "0" (Figure 4-5).

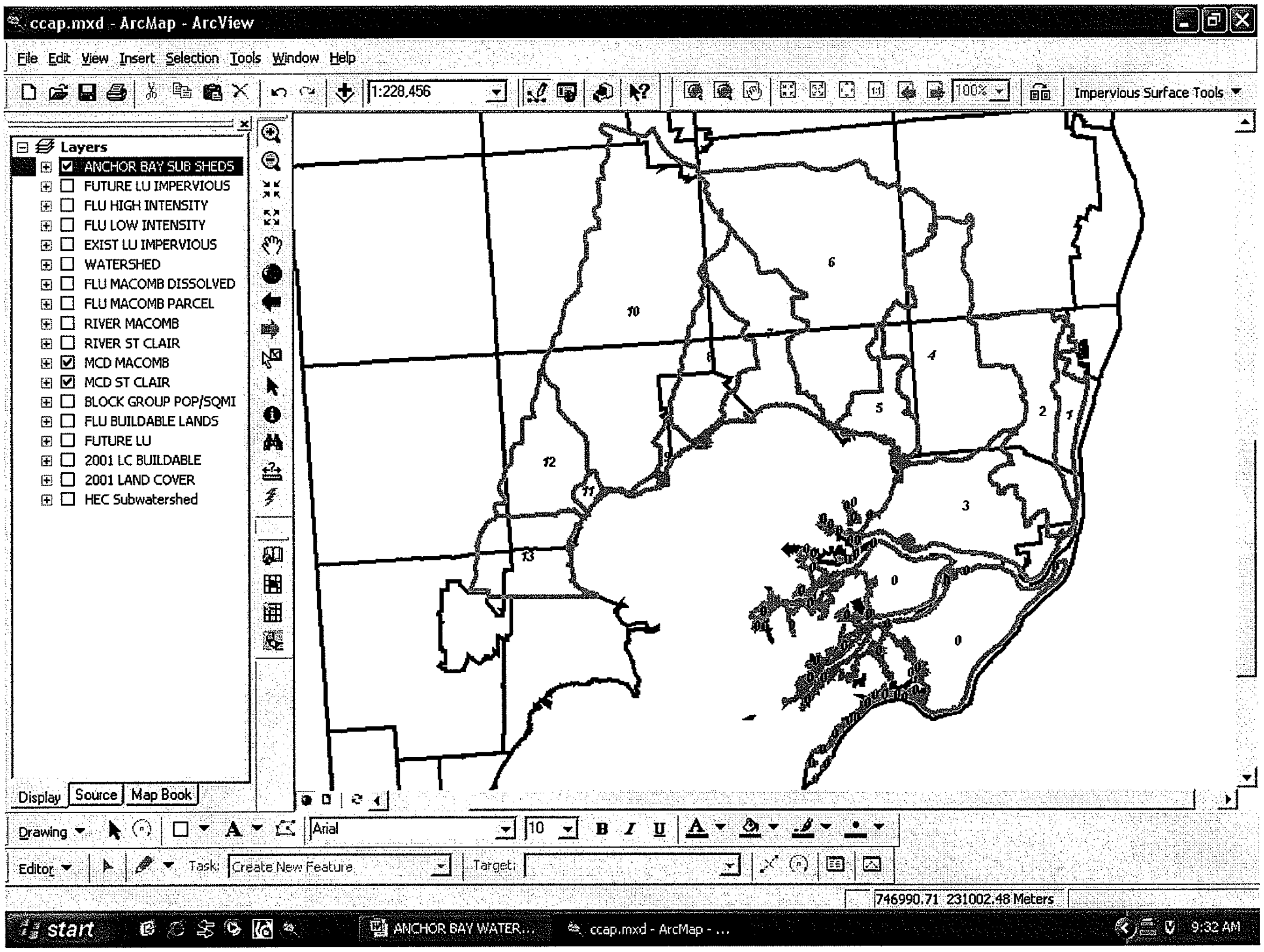



**Figure 4-5 – Subwatersheds**

## U.S. Census Population Data

U.S. Census Block Group polygon files are available for use from CGI Geographic Data Library. These files are consistent with the Michigan Framework base map which was chosen for this project. The "Census Data for Geographic Framework" application program allows users to select and download census data to a summary file that is readily imported into ArcView. The summary file contains the total population of each block group. It was linked to the Michigan Framework block group files which include areas of each block group. From the data, population density of persons per square mile was calculated and added as an attribute "POPDNS2000."

The layer representing the census block groups including population density is "BLOCK GROUP POP/SQMI." Population density is mapped in three classes:

- 1 to 250 persons per square mile
- 250 to 2,500 persons per square mile
- Greater than 2,500 persons per square mile

These class breaks were determined upon review of the natural population class breaks of communities within the Watershed. They are used to select impervious surface coefficients based on population density (Figure 4-6).

The analysis layer contains an analysis field for which percentage imperviousness is calculated. The field "LINK" represents a unique value to identify each block group/subwatershed combination.

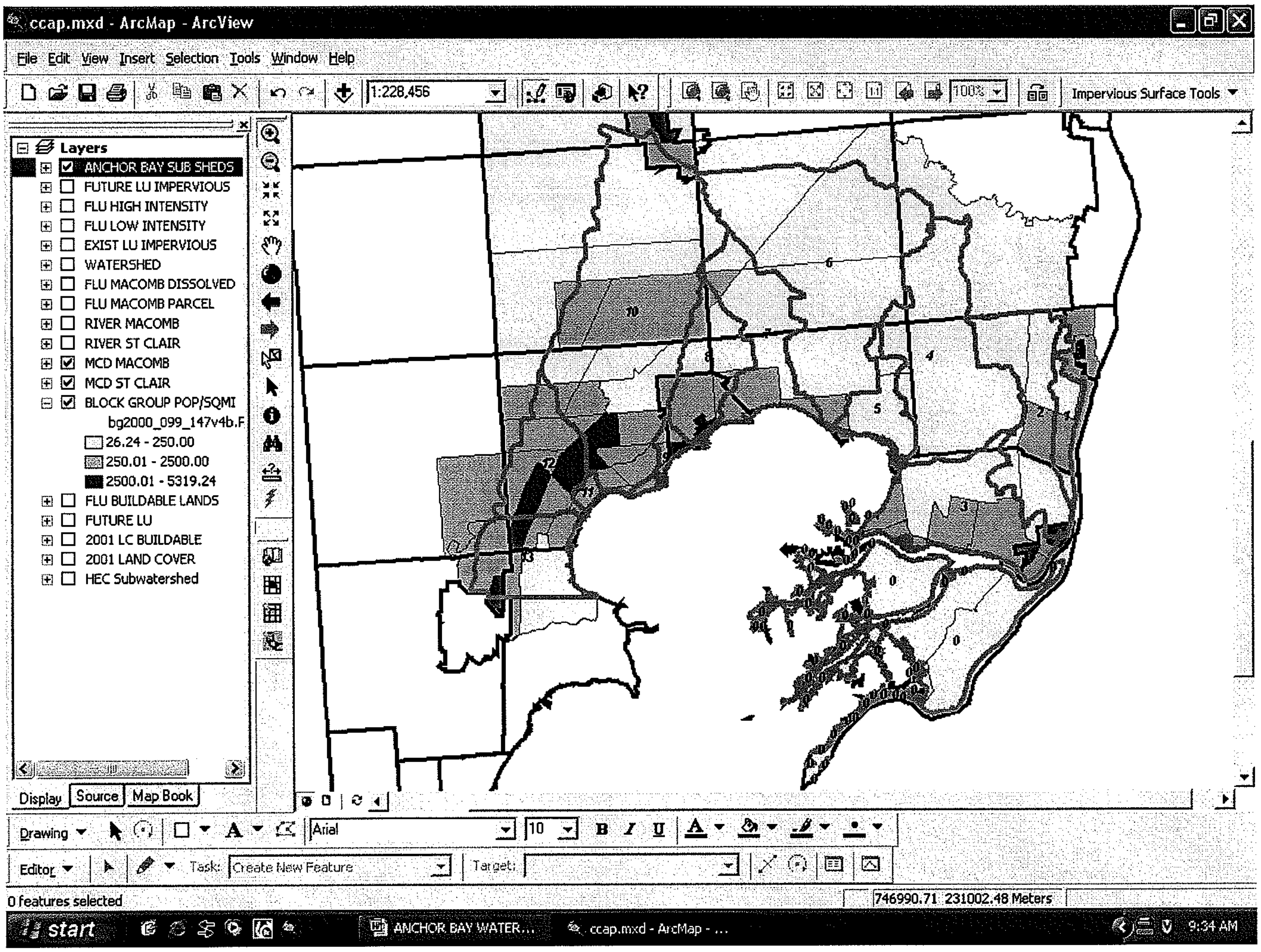



**Figure 4-6 – Population Density**

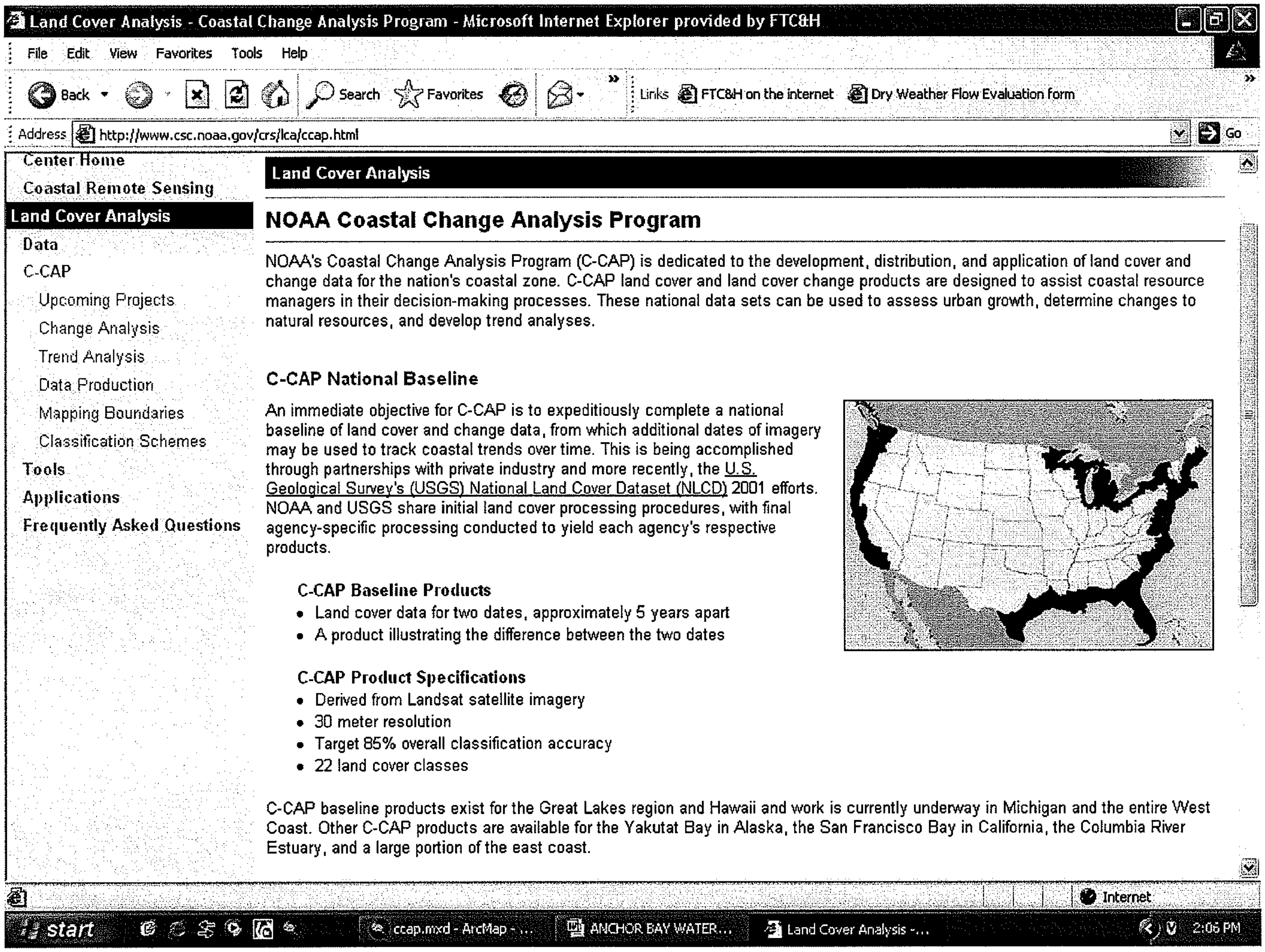
**Existing Land Cover**

The NOAA 2001 land cover data is provided by the NOAA Coastal Change Analysis Program (C-CAP). The data represents existing land cover and was developed to document changes in coastal habitat. Fortunately, the entire state of Michigan is captured in the C-CAP coverage area. The land cover classes include detail for wetlands and coastal lands, which are important to habitat management, and include less distinction for specific types of developed lands. The impervious surface parameters have been formatted to correspond to this data.

C-CAP Data Specifications:

- Derived from Landsat satellite imagery
- 30 meter pixel resolution
- Target 85% overall classification accuracy
- 22 land cover classes (19 of which are found within the Watershed)

This data is available for download at the NOAA Coastal Service Center Coastal Water Quality website: http://www.csc.noaa.gov/crs/lca/ccap.html (Figures 4-7 and 4-8).



Land Cover Analysis - Coastal Change Analysis Program - Microsoft Internet Explorer provided by FTC&H

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Land Cover Analysis

## NOAA Coastal Change Analysis Program

NOAA's Coastal Change Analysis Program (C-CAP) is dedicated to the development, distribution, and application of land cover and change data for the nation's coastal zone. C-CAP land cover and land cover change products are designed to assist coastal resource managers in their decision-making processes. These national data sets can be used to assess urban growth, determine changes to natural resources, and develop trend analyses.

### C-CAP National Baseline

An immediate objective for C-CAP is to expeditiously complete a national baseline of land cover and change data, from which additional dates of imagery may be used to track coastal trends over time. This is being accomplished through partnerships with private industry and more recently, the U.S. Geological Survey's (USGS) National Land Cover Dataset (NLCD) 2001 efforts. NOAA and USGS share initial land cover processing procedures, with final agency-specific processing conducted to yield each agency's respective products.

**C-CAP Baseline Products**

- Land cover data for two dates, approximately 5 years apart
- A product illustrating the difference between the two dates

**C-CAP Product Specifications**

- Derived from Landsat satellite imagery
- 30 meter resolution
- Target 85% overall classification accuracy
- 22 land cover classes

C-CAP baseline products exist for the Great Lakes region and Hawaii and work is currently underway in Michigan and the entire West Coast. Other C-CAP products are available for the Yakutat Bay in Alaska, the San Francisco Bay in California, the Columbia River Estuary, and a large portion of the east coast.

Internet

start ccap.mxd - ArcMap - ... ANCHOR BAY WATER... Land Cover Analysis -... 2:06 PM

**Figure 4-7 – NOAA C-CAP**

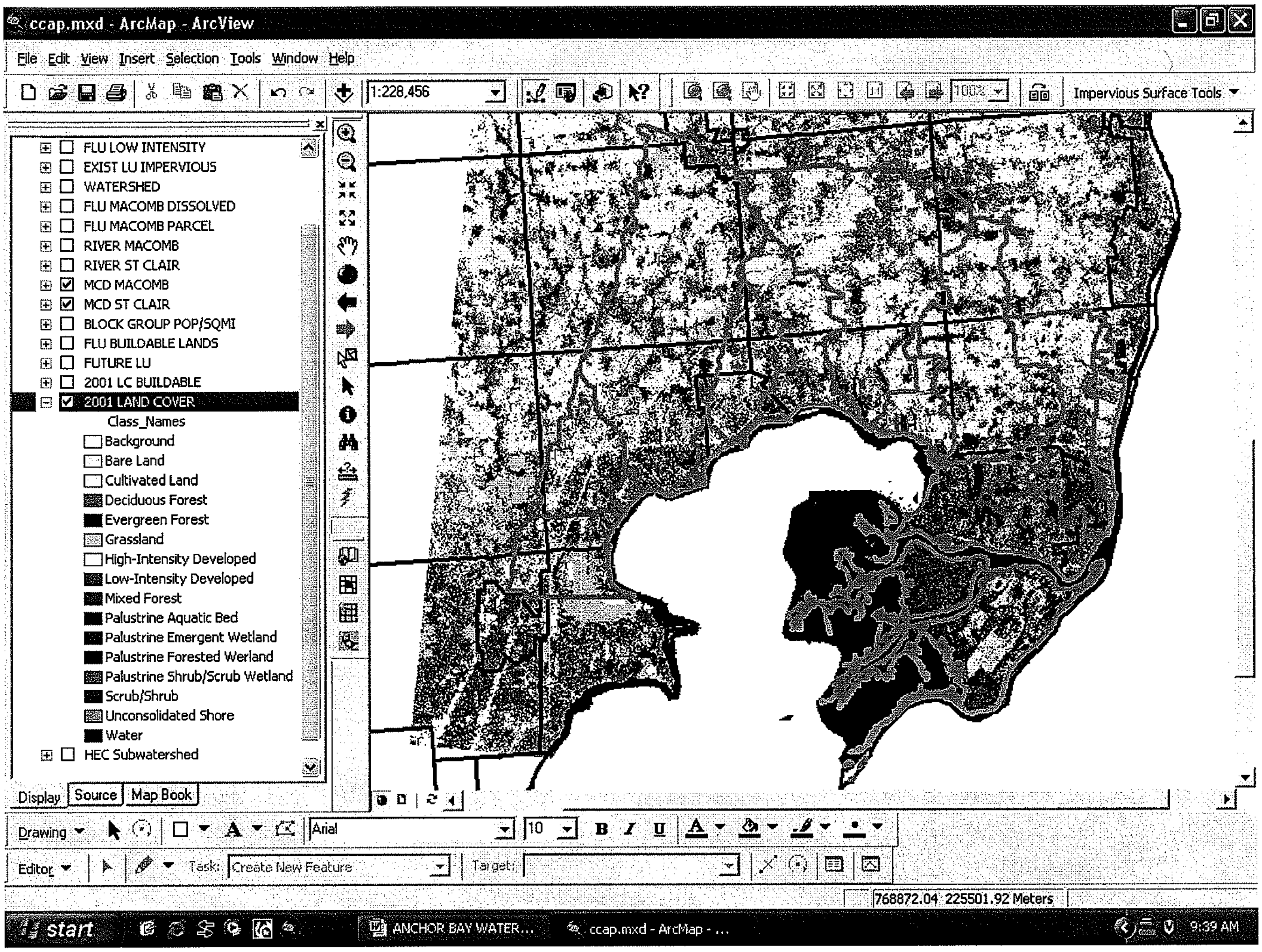



**Figure 4-8 – Existing Land Cover**

## PART TWO - EXISTING LAND COVER IMPERVIOUS ANALYSIS

The Watershed delineations, existing land cover, and population block group data collected is used to run ISAT. ISAT comes with a set of coefficients provided by the University of Connecticut based on impervious surface data for that state. Information on this source is included in the ISAT support documentation. The NOAA Coastal Services Center is currently working in cooperation with the Great Lakes Commission to develop an Integrated Coastal Management Tool for analyzing the impacts of various management decisions on the Lake St. Clair coastal habitat. This process uses ISAT and includes a plan to study the impervious surface coefficients based on Michigan, and more specifically eastern Michigan, land cover conditions. Although this information was not developed in time for use in the Watershed impervious surface analysis, it may become available in the near future. In the meantime, the values included with the ISAT tools are used in lieu of Michigan-specific data.

The ISAT coefficient set modeled after the Connecticut coefficient set provided with the tool (C-CAP_CT) was modified slightly to match the National Land Cover Database (NLCD) codes found in the Watershed.

The following classes were deleted from the given set:

- 20 Estuarine Aquatic Bed
- 21 Tundra
- 22 Snow/Ice

The following class was added to the new coefficient set:

- 0 Unknown, 0, 0, 0

The deleted classes are not found within the Watershed land cover data set and will cause errors in ISAT if they are included in the coefficient set. Likewise, if a background value of "0" is found within the dataset, it must have coefficients included, even though those values are zero. The coefficient set is saved as "ccap_anchorbay" (Figure 4-9).

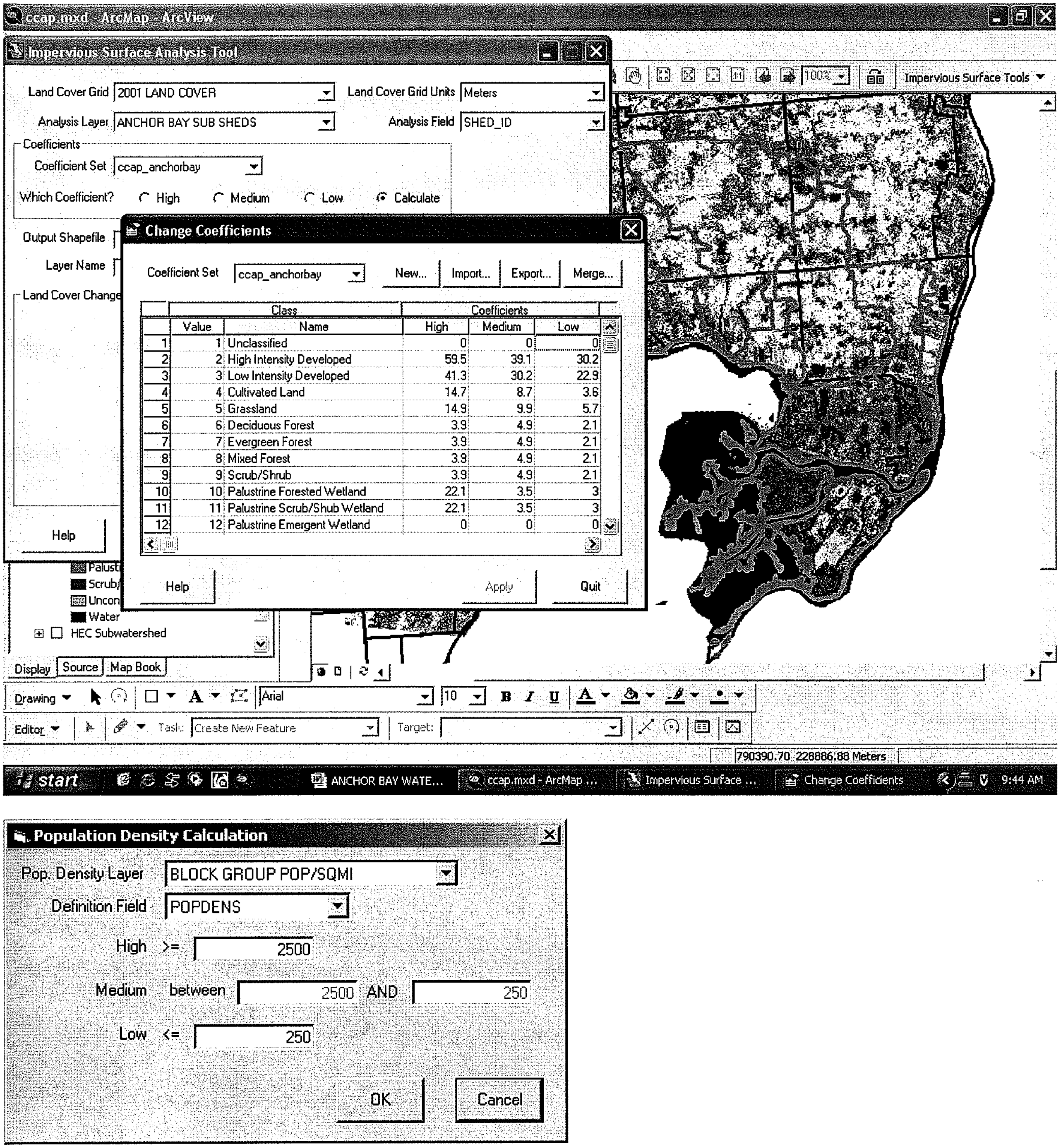



**Figure 4-9 – Existing Land Cover Subwatershed Data Entry**

The results are stored as an ESRI shape file and associated layer file and are automatically added to the ArcView project. The layer represents an analysis based on subwatershed delineations (SHED_ID). The default legend applied to the new layer indicates the potential impact to water quality based on the estimated percentage of imperviousness within each analysis field. Research has indicated that certain zones of stream quality exist that correspond to levels of imperviousness. Streams are most protected with a level of less than 10% imperviousness. Sensitive stream elements are lost from the system when the levels exceed 10%. A second threshold appears at about 25% impervious cover, where most indicators of stream quality consistently shift to a poor condition, such as diminished aquatic diversity (Schueler and Holland, 2000, Article 28).

- **PROTECTED:** Green areas are labeled <10%, which corresponds to less than 10% impervious surface area.
- **DEGRADED:** Yellow areas are labeled 10% to 25%, which corresponds to 10% to 25% impervious surface area.
- **IMPACTED:** Red areas are labeled >25%, which corresponds to greater than 25% impervious surface area.

The results are presented in tabular form by viewing the layer's attribute table (Figure 4-10). The attribute table contains four columns for each Analysis Field (SHED_ID): TotHects, TotISHec, pctIS, and Complete. TotHects is the total area within each analysis field. TotISHec is the total impervious surface area within each analysis field, and pctIS is the percentage of impervious surface within each analysis field. ISAT checks for polygons in the analysis layer that overlap NO DATA cells in the land cover grid. The Complete attribute indicates Y for yes, that a full calculation was made because there are no NO DATA cells, or N for no, that area calculations for these polygons exclude area where NO DATA cells were found. The land cover grid data provided was projected to Michigan Georef (meters), the same system used for the Michigan Framework base map. Therefore, the results are in hectares because the initial data input was in meters.

The ISAT parameters that created this layer are stored in a separate text file with a ".prm" extension. It can be opened as a text file in the same directory as the ArcView shape file. ISAT parameter reports for this project can be found in the Appendix 12.

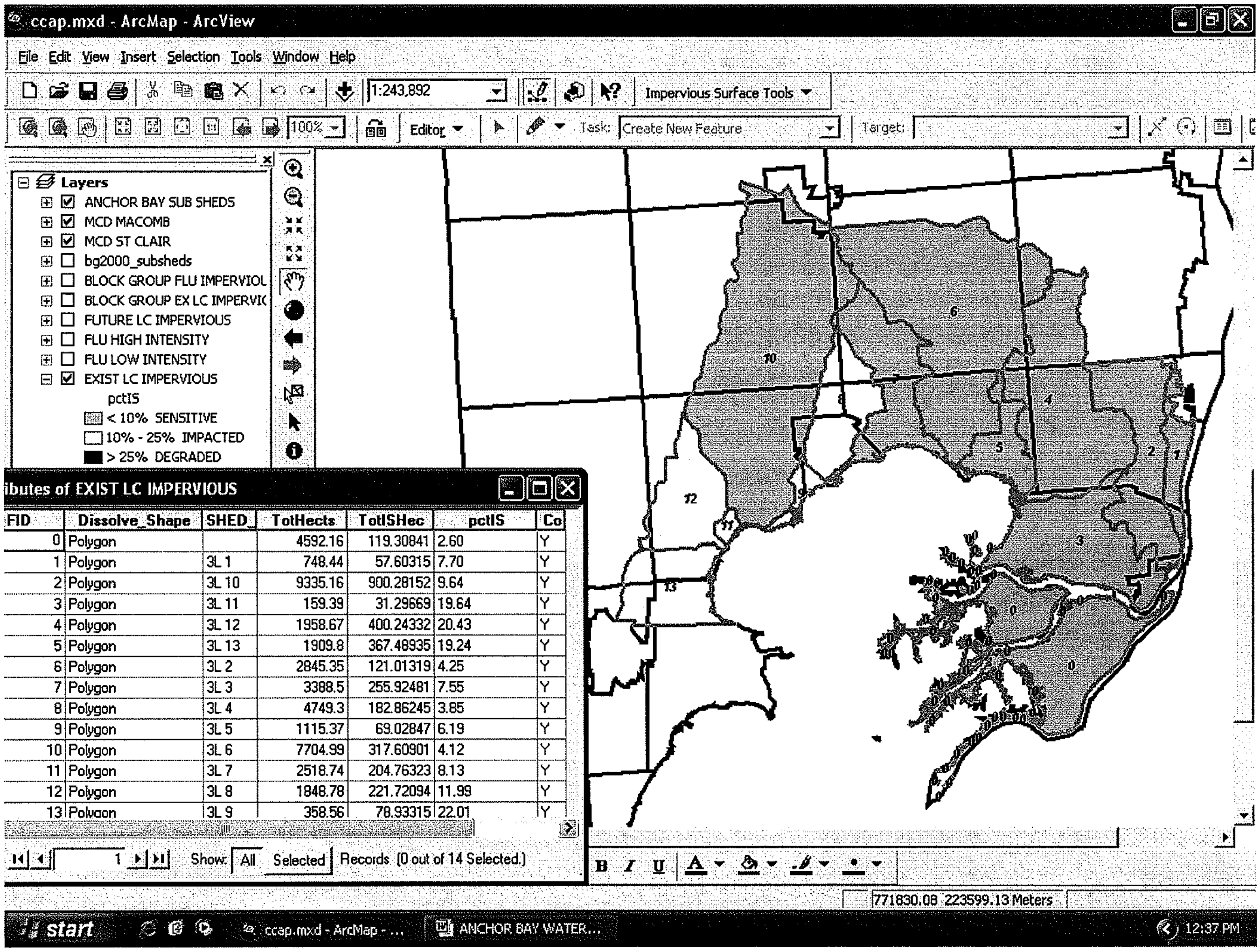



**Figure 4-10 – Existing Land Cover Subwatershed ISAT Results**

ISAT calculates the percentage of impervious surface area of selected geographic areas. These selected geographic areas could represent watersheds, subwatersheds, municipalities, subdivisions, census blocks, or any user-defined area boundary. Initial ISAT runs for the Watershed indicated that even at the subwatershed level, significant differences in land cover and population density were averaged out over a large area. Thus, the results were not specific to the individual communities or development areas within each community.

ISAT for existing land cover was run again, using the combination of census block groups and subwatershed boundaries as the analysis layer. The most significant differences can be found in high-intensity development areas along the Anchor Bay shoreline (Figures 4-11, 4-12, and 4-13).

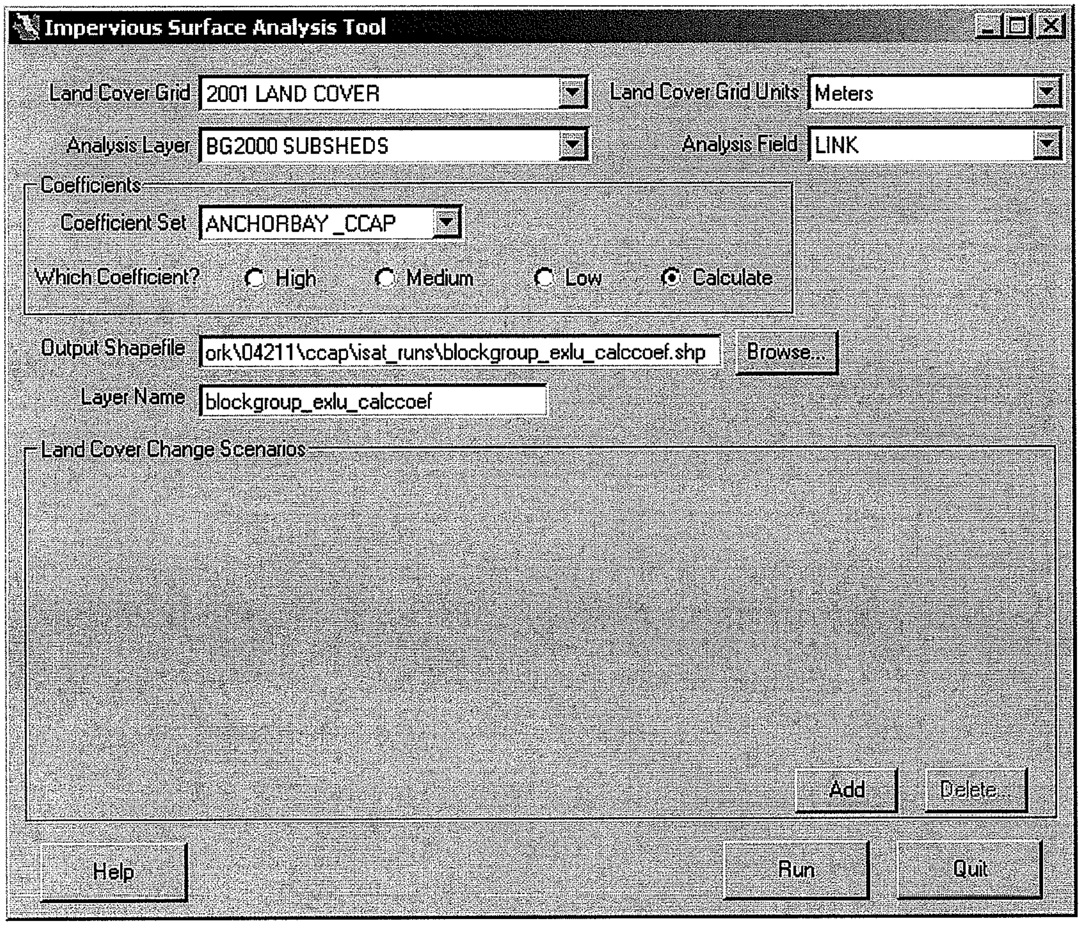



**Figure 4-11 – Existing Land Cover Block Group Data Entry**

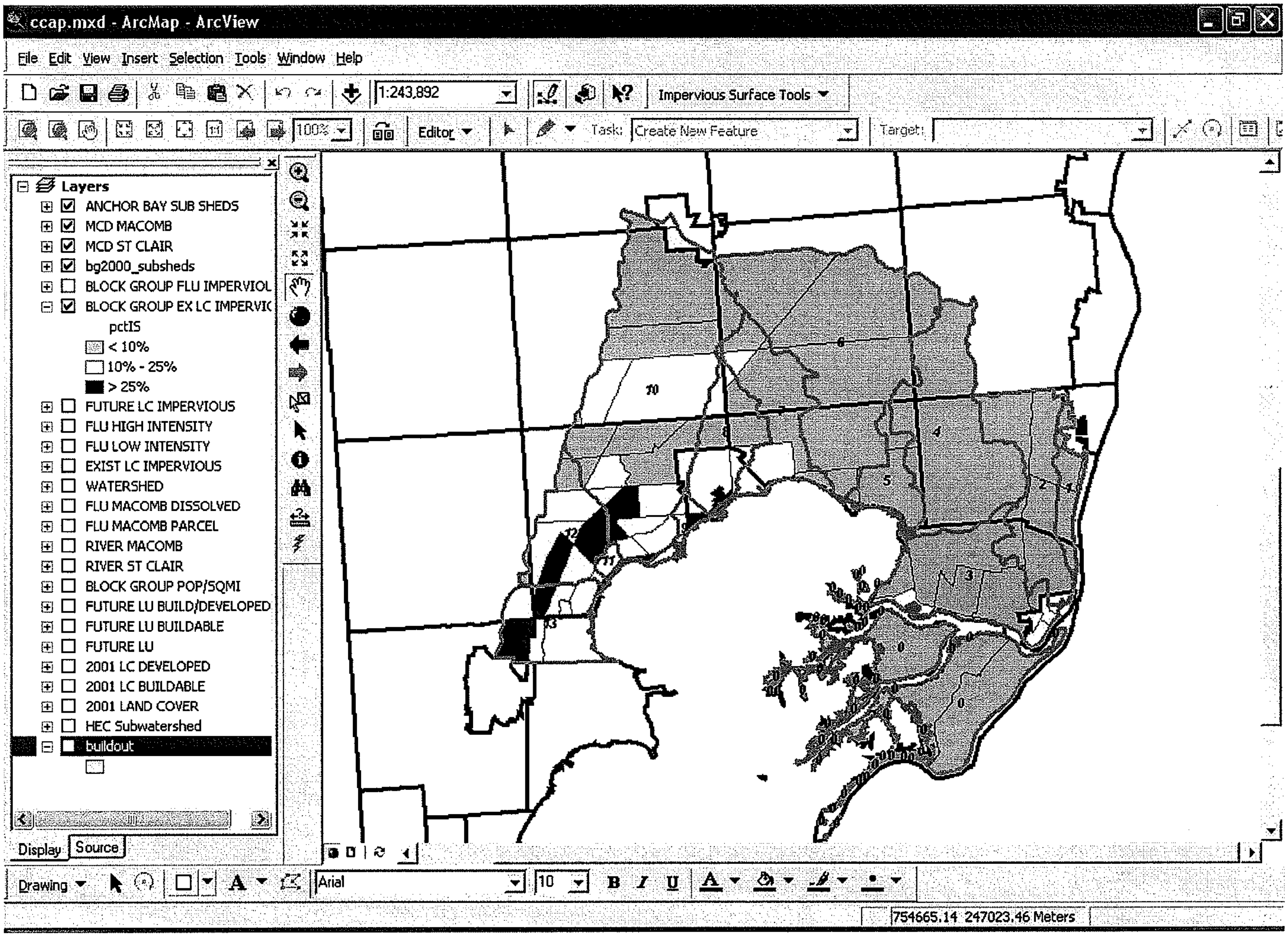



**Figure 4-12 – Existing Land Cover Block Group ISAT Results**

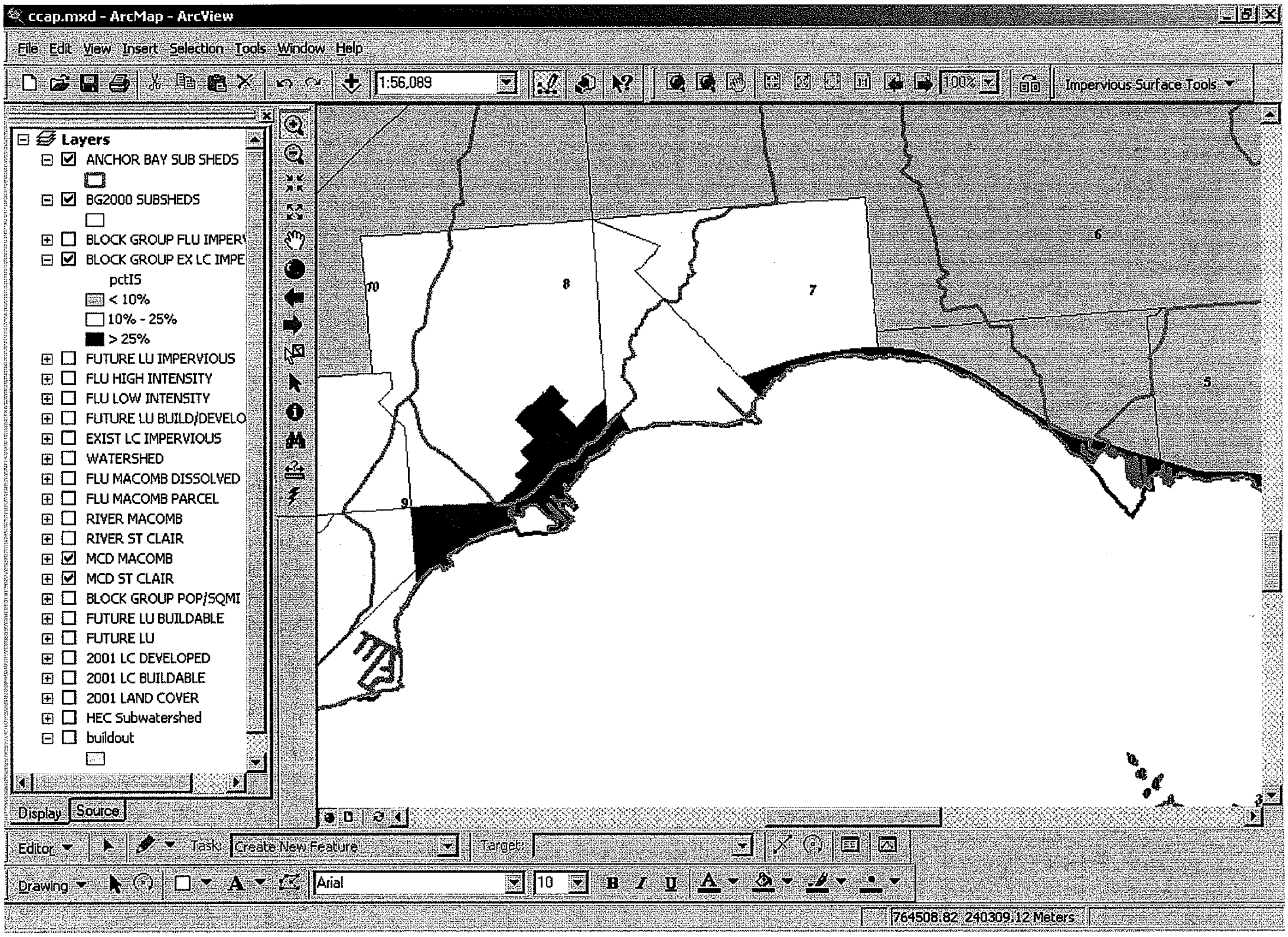



**Figure 4-13 – Existing Land Cover Block Group ISAT Results Anchor Bay Coastline**

## PART THREE - FUTURE LAND COVER CAPACITY IMPERVIOUS ANALYSIS

The capacity analysis illustrates the effects of development on impervious surfaces if land cover is permitted to develop according to local future land-use plans. The extent of impervious surface cover is used to establish the potential for stream quality degradation.

To create future land-use change scenarios, "unbuildable" lands in the existing land cover layer were identified. It is assumed that these areas will not be available for development even though they may be shown as such in the local future land use plans.

Unbuildable areas removed from future change scenarios include water and wetlands (NLCD GRID CODES 10-16, 18, and 19). The remaining area represents land cover area that is "buildable" (Figure 4-14).

Public lands which are not available for future development were also removed during this step. The State of Michigan Department of Natural Resources Surface and Mineral Lands layer was reviewed. In almost all cases, state lands were previously removed because they are classified as wetlands land cover. The remaining areas of state lands present throughout the Watershed are "mineral" rights only, and, therefore, do not affect surface development.

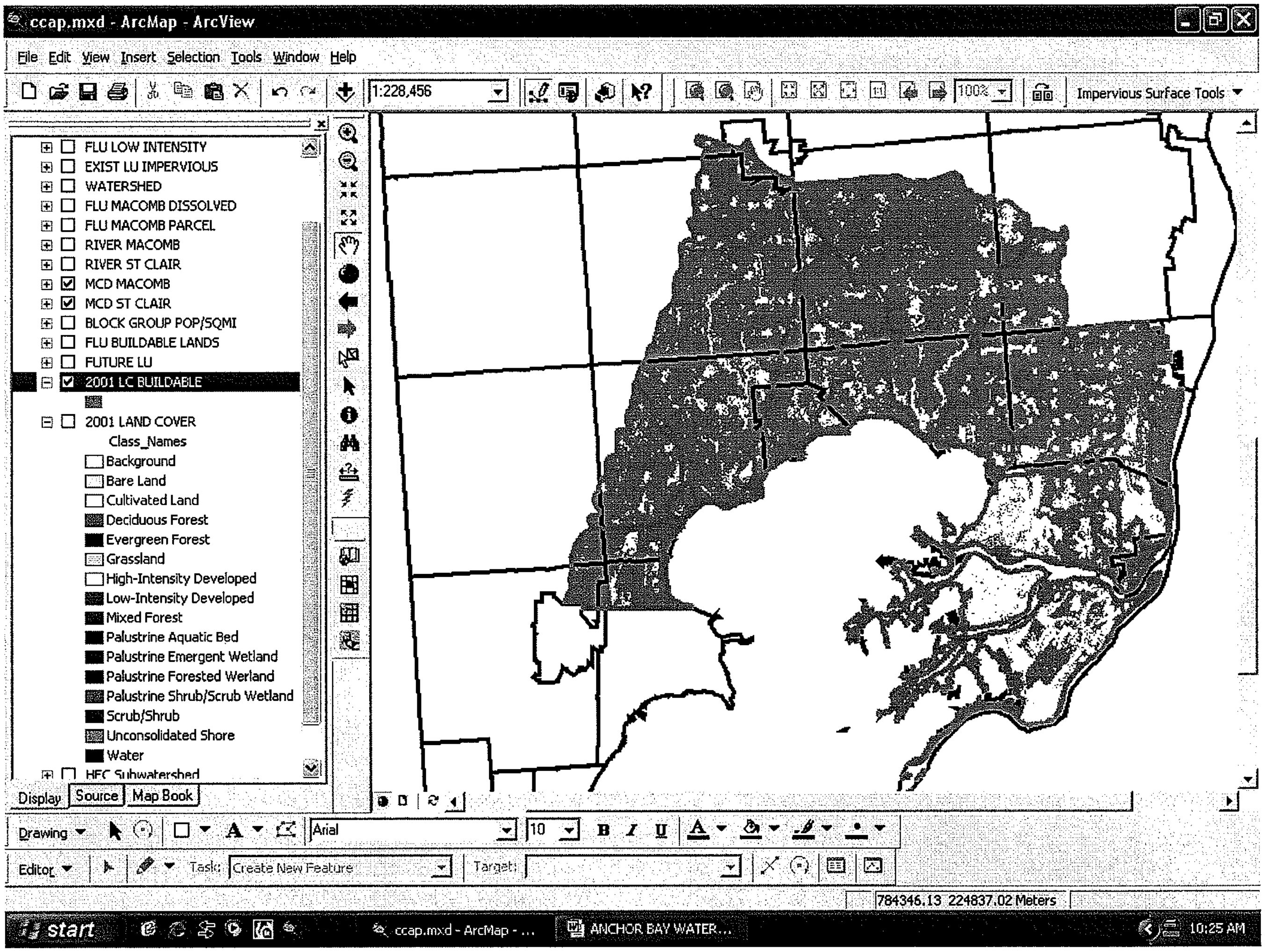



**Figure 4-14 – Existing Land Cover Buildable Lands**

Future land use plan layers were provided by the St. Clair County Metropolitan Planning Commission and Macomb County Planning and Economic Development. The data was compiled and dissolved to create a composite future land use layer for the Watershed (Figure 4-15).

Existing Land Cover: the type of existing surface cover.

Future Land Use: the type of use that may occur, an indication of surface cover.

Note: Land use and land cover are two differently defined datasets that were correlated for this analysis.

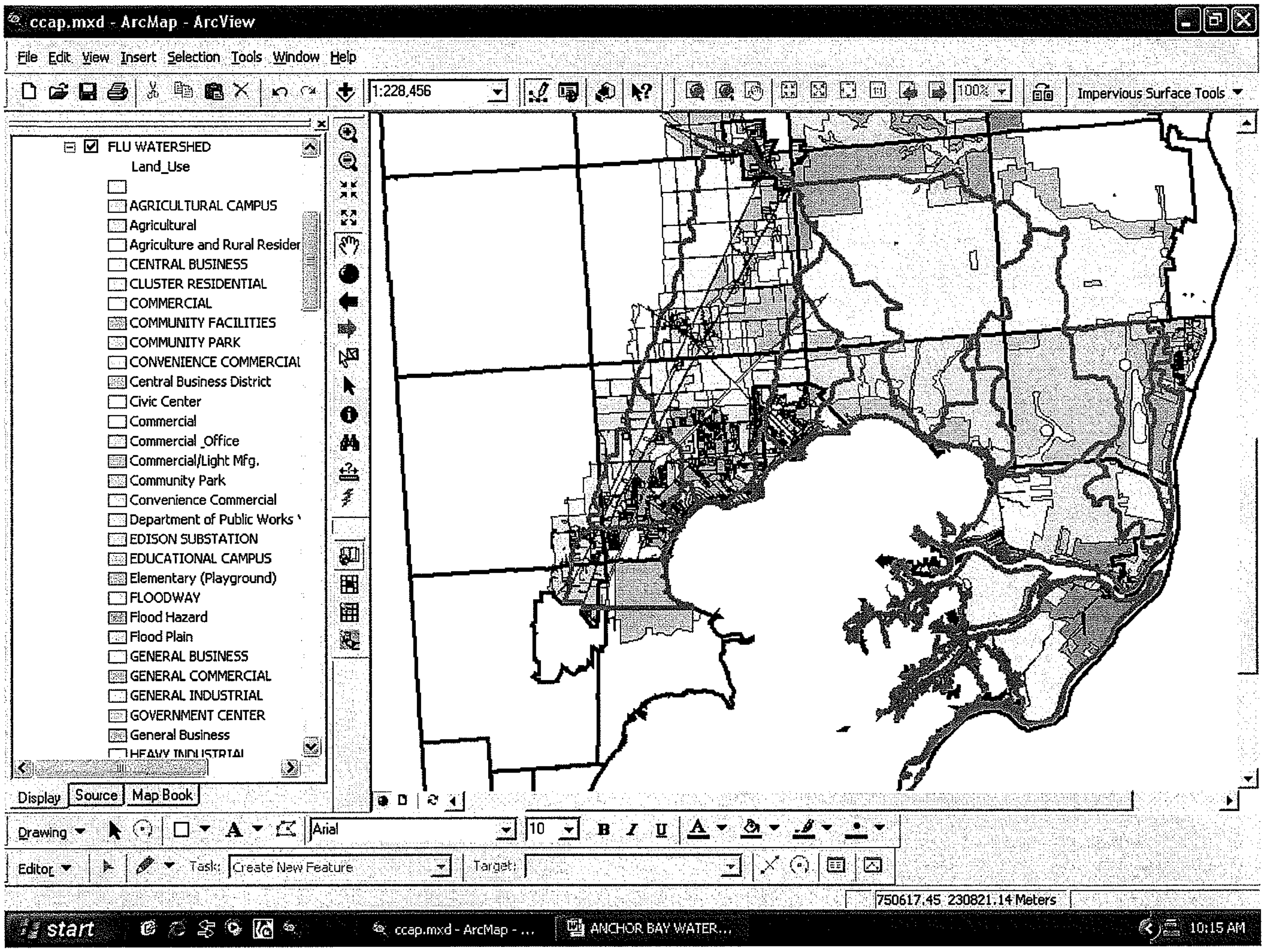



**Figure 4-15 – Future Land Use**

The future land use layer was clipped to the "buildable" lands layer. The remaining area represents "buildable" land area within the future land use map (Figure 4-16).

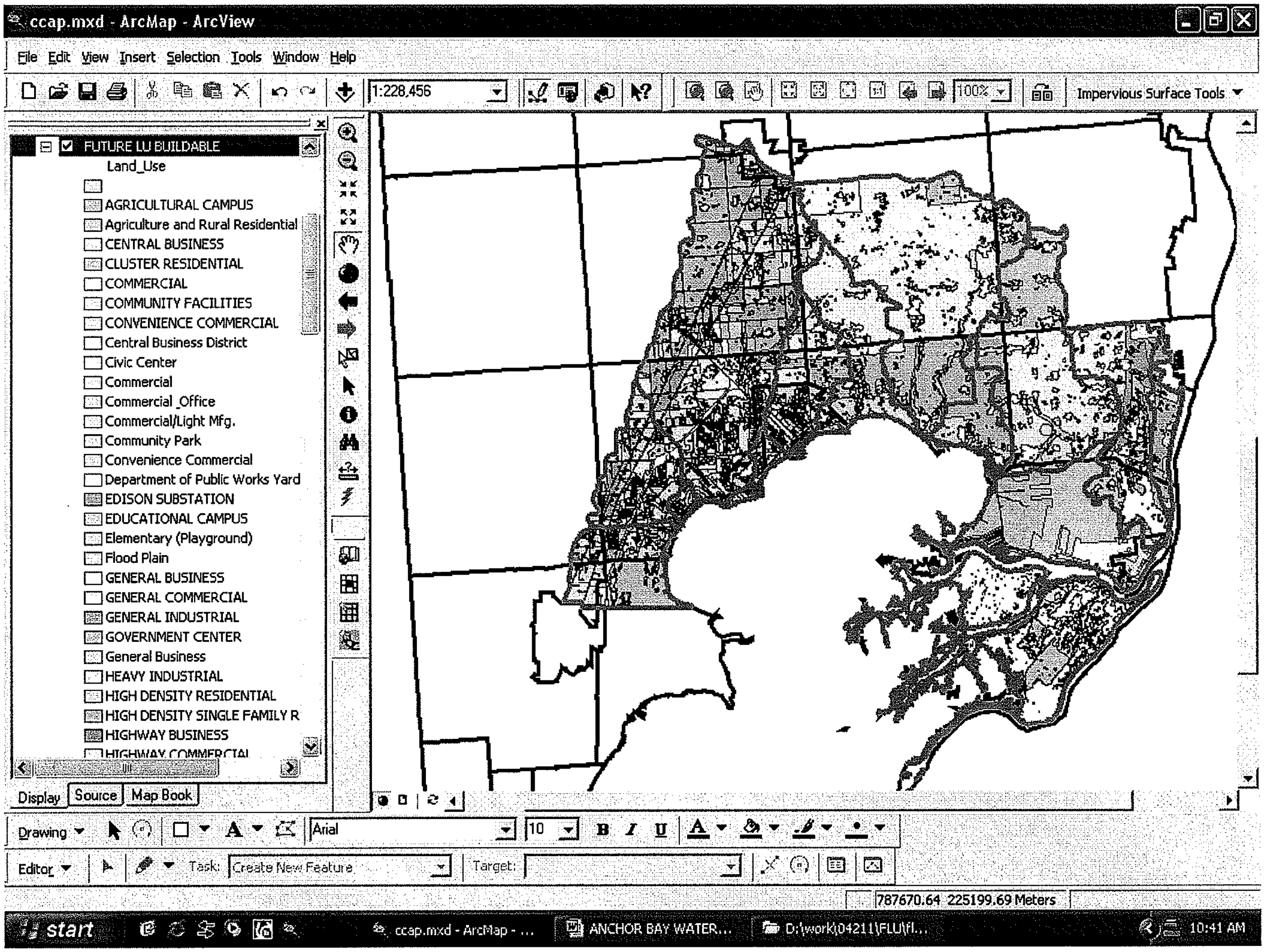



**Figure 4-16 – Future Land Use Buildable Lands**

Future land use maps are broad brush planning tools. They are not of significant detail to include all areas of actual recent development. Therefore, lands that have already been developed in the existing land cover were identified (Figure 4-17). This was particularly relevant in those areas where a future land use plan indicated low-intensity development, but existing land cover was already developed at a higher level. Notice that much of the higher-intensity development has occurred along roads. The parcel based future land use plans do not take developed road surfaces or spot developments into account, which can be a significant source of impervious surface cover.

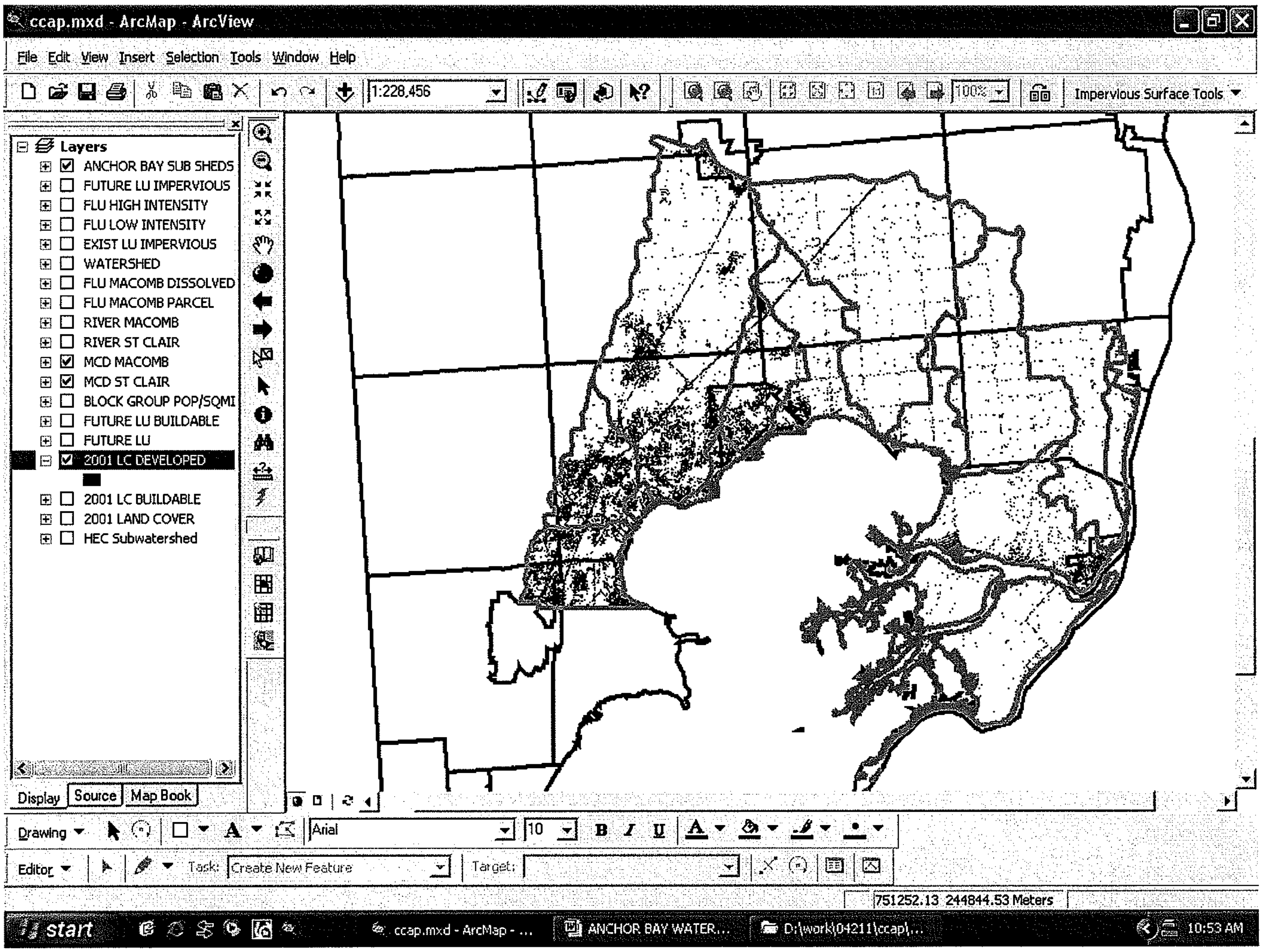



**Figure 4-17 – Existing Land Cover Developed Lands**

The future land use buildable lands were intersected with existing developed land cover (Figure 4-18).

The layer produced represents a future land use scenario for buildable lands which also accounts for existing developed land cover.

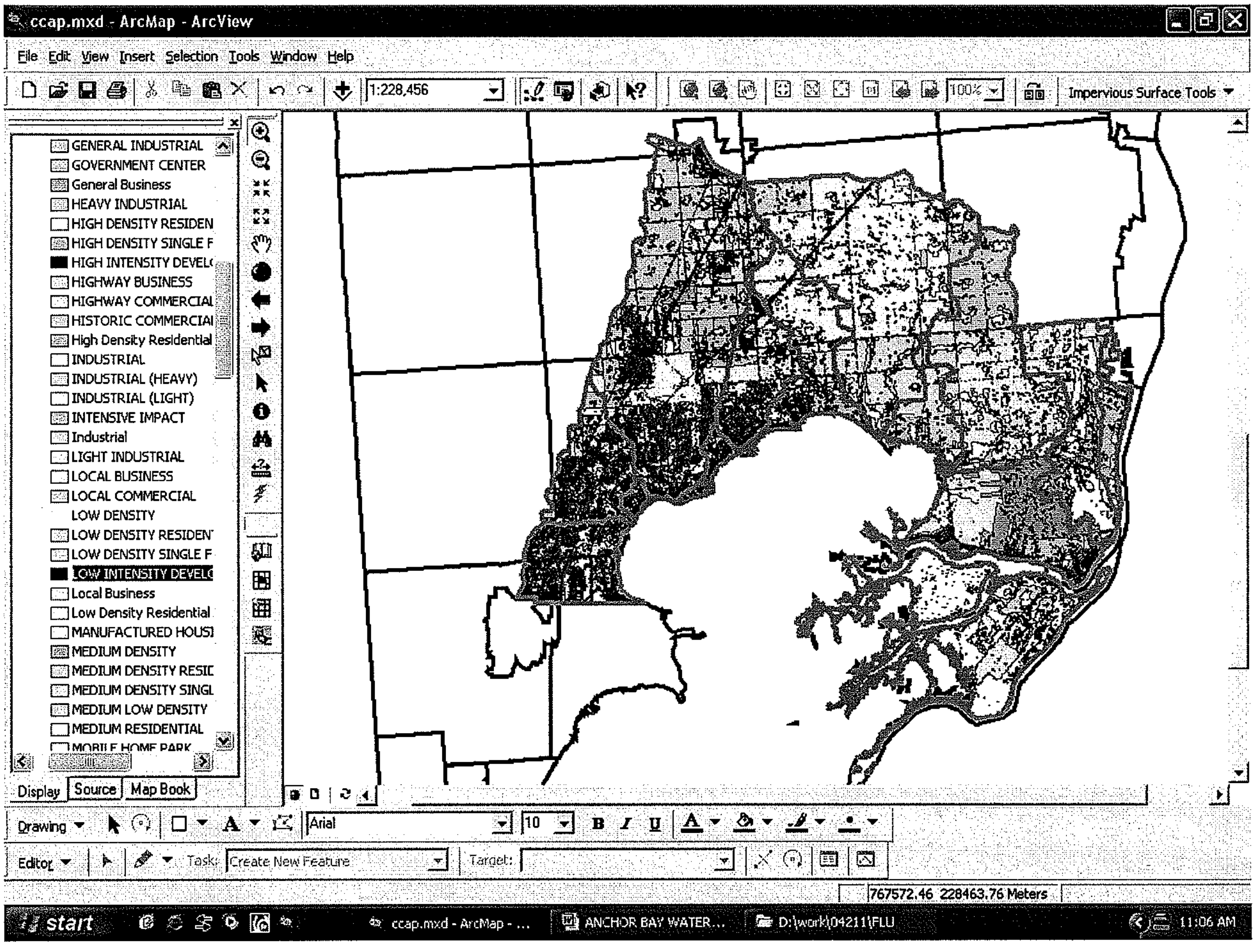



**Figure 4-18 – Future Land Use Buildable/Developed Lands**

A complete description of the C-CAP Classification Scheme can be found on the NOAA Coastal Service Center website: http://csc.noaa.gov/crs/lca/oldscheme.html. Assuming that existing developed lands will not revert to undeveloped lands in the future, only High-Intensity Developed (Class 2) and Low-Intensity Developed (Class 3) land classes were added for future land change scenarios.

> **Class 2 High-Intensity Developed:** *High Intensity, Developed Land includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of different land uses. The High-Intensity category contains areas in which a significant land area is covered by concrete and asphalt or other constructed materials.* ***Vegetation, if present, occupies < 20 percent of the landscape.*** *Examples of such areas include apartment buildings, skyscrapers, shopping centers, factories, industrial complexes, large barns, airport runways, and interstate highways.*

**Class 3 Low-Intensity Developed**: *Low-Intensity, Developed Land includes areas with a mixture of constructed materials (e.g., roofing, metal, concrete, asphalt) and vegetation or other cover.* ***Constructed materials account for 50% to 79% of the total area.*** *These areas commonly include single-family housing areas, especially in suburban neighborhoods, but may include scattered surfaces associated with all types of land use. As the percentage of constructed material cover decreases, this category grades into Cultivated, Grassland, Woody, and other land cover classes. A large building surrounded by several acres of grass, for example, might appear as one or more pixels of High Intensity Developed Land, one or more pixels of Low-Intensity Developed Land and many pixels of Grassland.*

From the revised future land use layer, the land use representing **high-intensity** and **low-intensity** development were selected and exported out to their own layers (Figure 4-19).

Comments were received from county planning units to establish the correlation between existing land cover classifications and future land use categories. A complete list of development intensity class codes for each county is provided in the Appendix 12.

High-Intensity Development uses include:

- Commercial
- Industrial
- Mixed-use
- Multi-family residential
- Shopping
- Transportation
- Single-family residential over 4 dwelling units/acre

Low-Intensity Development uses include:

- Single-family residential under 4 dwelling units/acre
- Public/semi-public uses
- Rural preservation
- Recreation

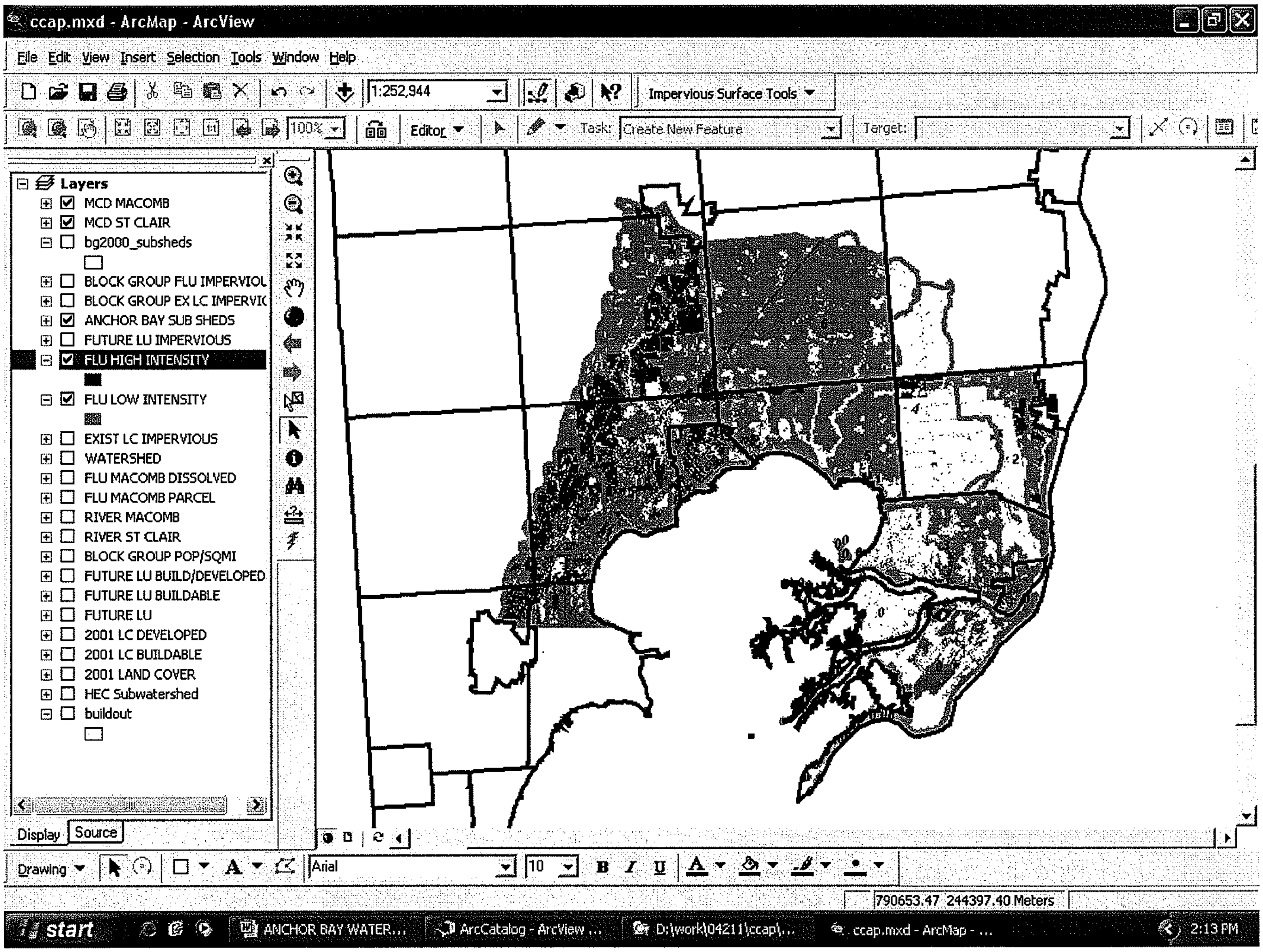



**Figure 4-19 – Future Land Use High/Low Intensity**

ISAT was run using High- and Low-Intensity Developed layers as "land cover change scenarios" to account for proposed changes in existing land cover. The program calculated the percent of impervious surface by assigning the future land use values for high- and low-intensity areas to the underlying existing land cover grid pixels. The percentage of impervious surface layer generated indicates the future land use plan and land cover changes over approximately the next 20 years. A side-by-side comparison of the existing and future scenarios attribute tables illustrates the actual percentage increases for each subwatershed (Figures 4-20 and 4-21).

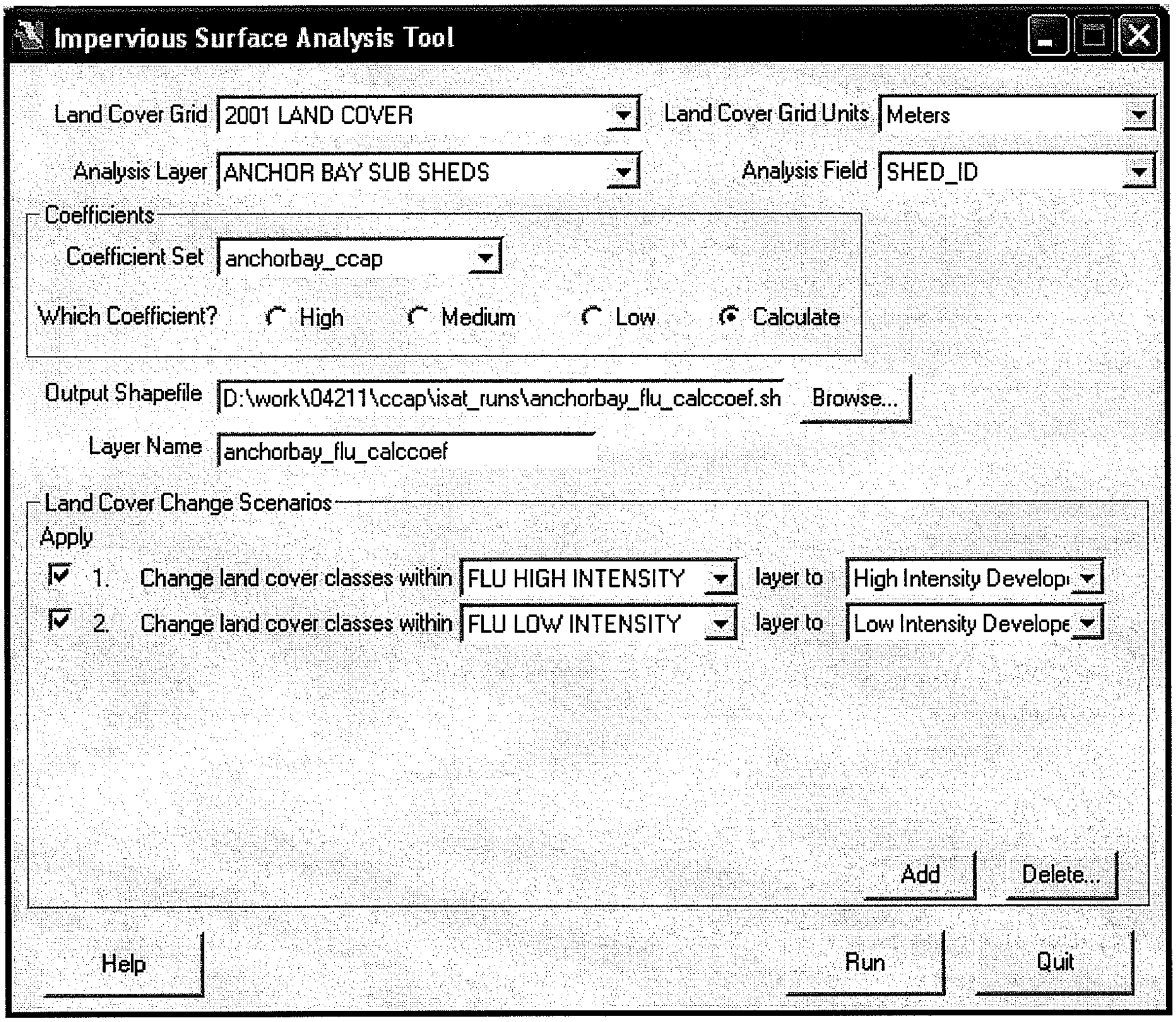



**Figure 4-20 – Future Land Use Subwatershed Data Entry**

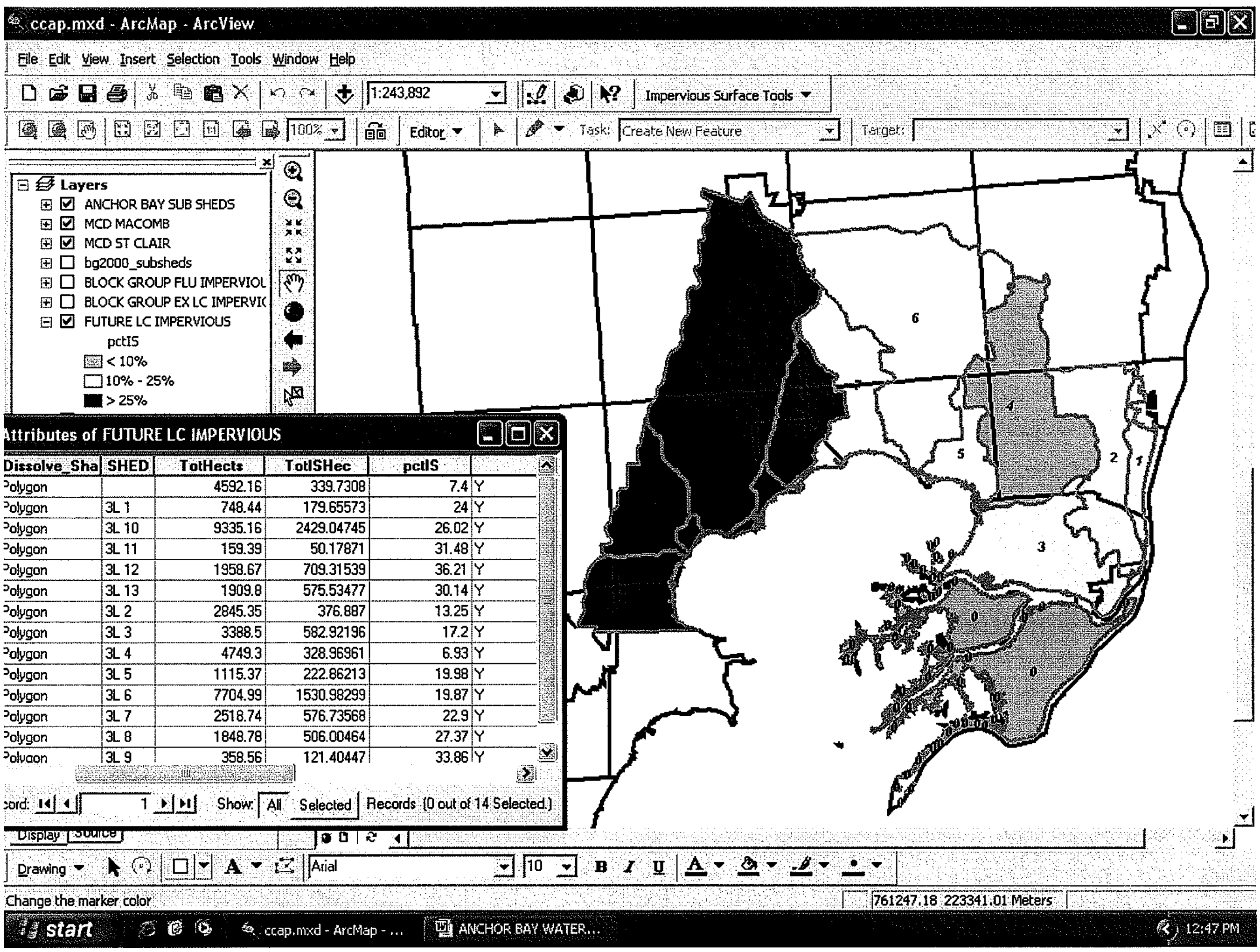



**Figure 4-21 – Future Land Use Subwatershed ISAT Results**

ISAT for future land cover was run again, this time using the combination of census block groups and subwatershed boundaries as the analysis layer. The most significant differences can be found in high-intensity development areas along the Anchor Bay shoreline (Figure 4-22).

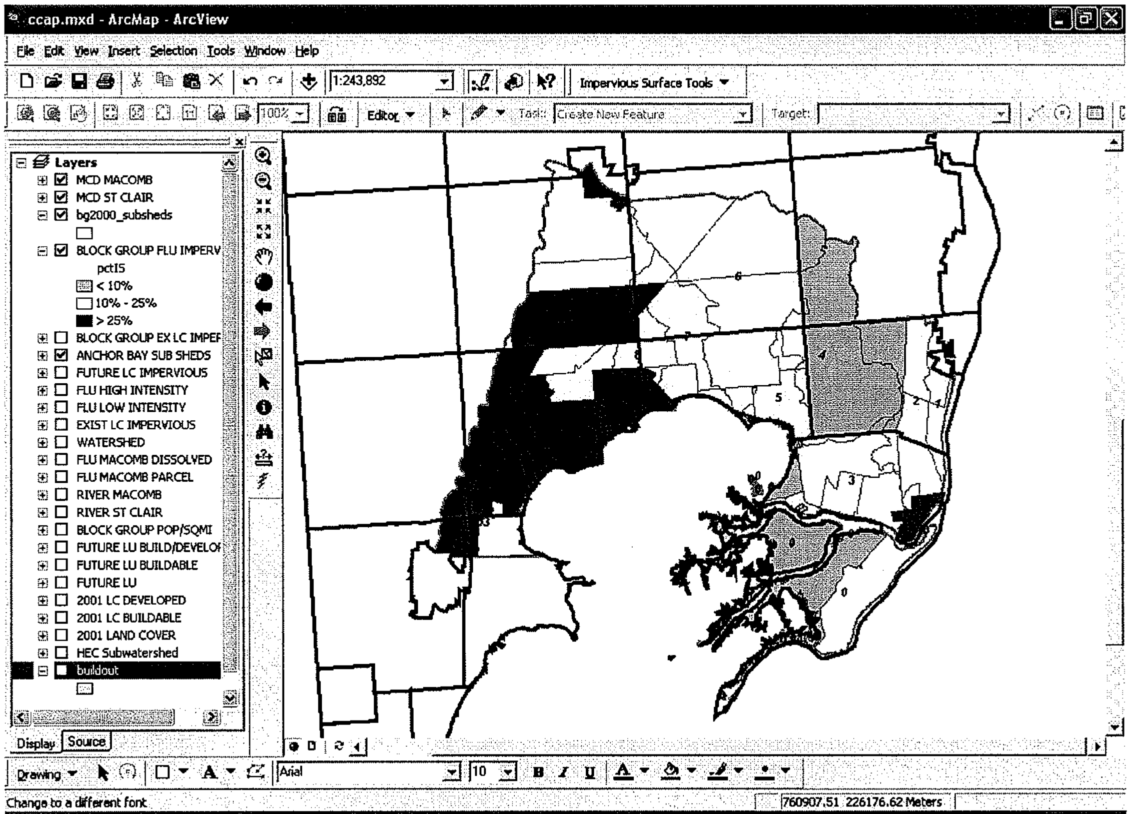



**Figure 4-22 – Future Land Use Block Group ISAT Results**

## PART FOUR - CONCLUSIONS AND APPLICATIONS AT THE LOCAL LEVEL

A build out analysis is a feasible and cost-effective indicator of water pollution that can provide a solid foundation for a community's plan of action. Impervious coverage is a readily identified, measurable aspect of the landscape, facilitating its use in both planning and regulatory applications. The establishment of consistent and defendable measures of imperviousness enables the development of strategies for community and watershed planning, site planning, and local regulations. The ability to project future land use and its associated imperviousness can give the land use planner a link between development and water quality.

Impervious cover has been documented to have a strong influence on water quality. Land use planners can use this information to critically analyze the degree and location of future development that is expected to happen in a watershed. Land use planning ranks as perhaps the single most important watershed protection tool. A goal of a land use planner should be to plan for development toward subwatershed that can support a particular type of land use and/or density (Schueler and Holland, 2000 Article 27). The basic goal of a watershed management plan is to apply land use planning techniques to redirect development, preserve sensitive areas, and maintain or reduce the impervious cover within a given subwatershed.

The classification of the subwatersheds of sensitive, degraded, and impacted can assist the communities in developing goals and criteria for development. With these goals and criteria in place, developers and consultants can refer to the subwatershed and can determine applicable site requirements for that particular subwatershed (Schueler and Holland, 2000 - Article 29).

Sensitive subwatersheds, with 0% to 10% impervious cover, should have a goal of maintaining predevelopment hydrology and biodiversity, and setting limits on site development impervious cover. To protect the streams, wide buffers are recommended through land acquisition or conservation easements.

Degraded subwatersheds, with 10% to 25% impervious cover, should have a goal of limiting degradation of stream habitat and quality through setting an upper limit for the watershed imperviousness. Implementation practices should focus on pollutant removal and channel protection measures.

Impacted subwatersheds, with over 25% impervious cover, should have a goal of minimizing downstream pollutant loads by preventing flooding and creating preservation areas to reduce the effects of flooding.

Creating a plan based on these goals can protect rivers, lakes, and streams from the cumulative effects of development in a watershed. This method of classifying and managing urbanizing watersheds, based on current or projected impervious cover, can improve the effectiveness of practices implemented by limiting the amount of new impervious cover that can be created.

Ordinances to assist in reaching those goals will be explained in the final chapter of this report.

# CHAPTER 5 - MODEL STORM WATER ORDINANCE

This section summarizes the background, purpose, and multiple issues to be addressed in an effective storm water ordinance. A copy of the model storm water ordinance for Anchor Bay communities is included in Appendix 13.

Storm water runoff is rainwater and snowmelt that runs off land and enters rivers, lakes, streams, or wetlands. Effective management of storm water runoff helps to provide watershed protection and is a critical need for the communities of Anchor Bay.

Storm water runoff increases as land is developed and the rainwater can no longer soak into the ground. There are two important attributes to this increase. First is the high runoff rate. The second is the increased volume of runoff water. In addition, storm water runoff picks up pollutants as it flows across the urban, suburban, and agricultural environments then delivers them into downstream waters, causing water quality problems. Storm water runoff impacts local communities through flooding, stream channel erosion, damage to property, water quality impairment, habitat destruction, and diminished quality of life. In fact, storm water runoff is the single most important cause of water quality impairment in the Anchor Bay Watershed (Watershed).

The model ordinance was developed specifically for cities, villages, and townships in the Watershed. It fulfills several aspects of the federal/state mandated storm water National Pollutant Discharge Elimination Systems (NPDES) Phase 2 program:

- Provides legal authority for the illicit discharge elimination program
- Integrates control of erosion and sediment from construction sites with the county program
- Establishes a program for post-development storm water management for new development and redevelopment, including:
  - Stream bank protection
  - Flood damage prevention and
  - Water quality measures
- Sets up a fee structure so the cost of controlling development is borne by developers, not the general public

- Requires that storm water management facilities are properly maintained by the property owners

- Provides the means for enforcement as a municipal civil infraction

The management of storm water runoff from construction sites is very important, because the soil is extremely vulnerable to erosion when the vegetation is removed. If the soil is eroded by the raindrops or the flowing storm water, not only do the soil particles muddy the water, but pollutants such as phosphorus, litter, bacteria, and pesticides are transported to a nearby river, lake, stream, or wetland. The soil particles often settle out as sediment interfering with aquatic life and stream flow. In Michigan, counties generally have the responsibility for a soil erosion and sedimentation control program. The model ordinance provides local government support to the county program and expands on it to include construction site waste and litter.


Development sites after the construction phase must have proper storm water runoff facilities. This is vital in controlling the impacts of development on our watersheds and water resources. Development changes the land surface by creation of impervious surfaces such as rooftops, roads, and parking lots. This has a number of effects. First, it increases the peak flow rate, the total volume of water, and the velocity of storm water runoff from a site. This leads to increases in the occurrence of flooding, degradation of stream channels, stream warming, and loss of aquatic biodiversity. Secondly, runoff from developed areas contains a variety of pollutants that are detrimental to water quality including sediment, nutrients, pesticides, bacteria, litter, heavy metals, and petrochemicals. Efforts to control the impacts of development and associated storm water runoff are typically in the form of best management practices (or BMPs) that either reduce runoff volume by infiltration, or detain and treat storm water to reduce pollutant levels and control the peak flow rate of runoff.

No ordinance or any number of BMPs can eliminate the impact of development. All development inevitably has an impact on the surrounding environment. Local ordinances only function to limit the impact of development to acceptable levels. This model ordinance partially resulted from state-of-the-art engineering analysis of Anchor Bay tributaries. Many local ordinances are based solely on experience elsewhere. Therefore, the provisions of this ordinance are more defensible if challenged in court.

The ordinance addresses the post-development storm water management requirements for new development and redevelopment sites through a permit requirement. The permit application must include a drainage plan that contains the details of how the development will address the post-development storm water runoff quality and quantity impacts, resulting from the permanent alteration of the land surface, as well as the nonpoint source pollution from land use activities. The ordinance also outlines the water quantity and quality performance standards for managing runoff and specifies requirements for using BMPs, in order to protect public health and safety, protection of public and private property, and

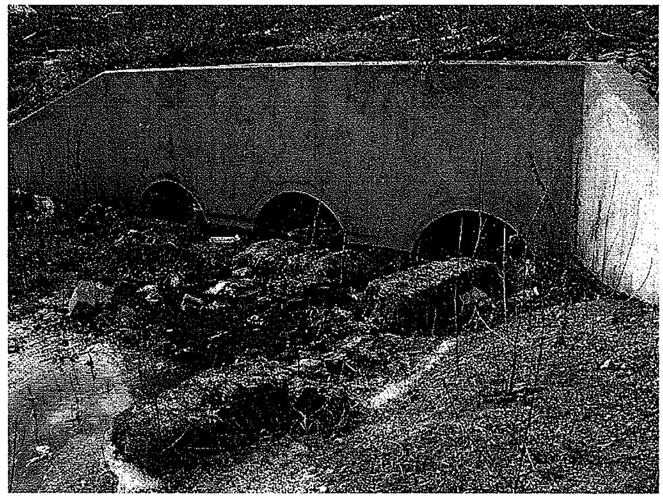
environmental protection. The release rate of storm water is limited to protect the stream bank and to protect stream channel stability, aquatic habitat, and water quality. Flood damage prevention is provided by keeping buildings out of the floodplain and by requiring storm water detention. The ordinance requires that natural drainage patterns be retained to the fullest extent possible. Infiltration may be required where groundwater flow is important to protect wetlands or other natural resources. Low impact development (LID) techniques are encouraged to reduce the runoff volume, as well as rate. Often these techniques result in reduced size of detention facilities. The ordinance includes a provision that allows the local government to require storm water treatment for areas with higher than average potential for storm water pollution (hot spots).

Design standards are included in the ordinance to help developers comply with the performance standards. Provisions are included to waive requirements where unnecessary to the purpose of the ordinance. The "Stream Protection" standard was selected as a direct result of the research conducted in the Watershed. A summary of the design standards recommended for the storm water ordinance is shown in Table 5-1.

**Table 5-1 – Summary of Design Standards for Model Storm Water Ordinance**

| CRITERIA | STANDARD | ALTERNATE | COASTAL ZONE |
|---|---|---|---|
| Flood Control | Detention of 100-year runoff volume with a maximum allowable release rate of 0.15 cfs/acre of developed site | 1. Detention required to match existing flows or downstream capacity if standard detention criteria will have a negative effect.<br>2. No detention required if un-detained discharge to pond/wetland will have no measurable effect on water levels.<br>3. In Crapau Creek, detention of 100-year runoff volume with a maximum allowable release rate of 0.1 cfs/acre of developed site is required | Direct discharge to Anchor Bay and St. Clair River |
| Stream Protection | Extended detention (24-hour) of runoff produced by a 1.5-year storm event from developed site | No detention required if un-detained discharge through a pond/wetland does not increase streambank erosion | Direct discharge to Anchor Bay and St. Clair River |
| Water Quality | Treat first 0.5-inch of rainfall through:<br>1. Permanent pool<br>2. Extended detention<br>3. Infiltration<br>4. Other treatment device (filter, vegetation, swirl concentrator) | Same as Standard | Same as Standard |
| Spill Protection | Containment or treatment required in areas that have high potential for storm water contacting polluting materials. | Same as Standard | Same as Standard |
| Groundwater Recharge | May require infiltration to avoid an increase in runoff volume or where it is important to sustain groundwater levels, such as for perennial streams or wetlands. | Same as Standard | Not required |
| LID (reducing runoff volume through impervious area reduction, infiltration, interception and re-use) | Encouraged to reduce runoff volume and rate of discharge. | Same as Standard | Encouraged to reduce size of water quality controls |

The fee system established by the ordinance provides that all costs associated with a development are paid by the developer through an escrow account. In addition, the developer would need to provide a financial guarantee to ensure that the storm water runoff facilities are completed as approved. Procedures are included to deal with permit termination at the conclusion of the project, the with project partially completed, and before the project begins.



Proper maintenance is important to the effective control of storm water runoff. Maintenance agreements are required to ensure that the drainage plans are properly implemented. If a property owner fails to comply, the local government may perform the maintenance and obtain reimbursement from the property owner.

The ordinance prohibits illicit discharges and illegal connections to provide communities with the authority to deal with these discharges, and establishes enforcement actions for those properties found to be in noncompliance. An illicit discharge is any discharge to a storm drainage system or surface water that is not composed entirely of storm water and is not otherwise specifically authorized. Illicit discharges include sewage, fuel spills, litter, and pollutants washed off of products or wastes.

Implementation will be the key to successful storm water management in the Watershed. As part of the federal/state storm water NPDES Phase 2 program, each community in an urbanized area, including all communities in the Watershed, must adopt a Storm Water Pollution Prevention Initiative. This document will include specific dates for accomplishing various tasks such as passing a storm water ordinance.

# REFERENCES


Andy Ward, J. David Allen, *Benefits of Two-Stage Ditches in Agricultural and Urban Watersheds, Workshop Notes,* August 25, 2004.

Camp Dresser & McKee, *Storm Water Management Plan for the Buck and Plaster Creek Watersheds*, Kent County, Michigan, 1991.

Dave Rosgen, *Applied River Morphology*, 1996.

Floyd A. Huff and James R. Angel, *Bulletin 71, Rainfall Frequency Atlas of the Midwest*, Midwestern Climate Center and Illinois State Water Survey, 1992.

Fred Fuller, *Rules of the St. Clair County Drain Commissioner, Procedures and Design Criteria for Stormwater Drainage in Development Plans,* 2004.

*Maryland Stormwater Design Manual*, Maryland Department of the Environment, 2000.

*Rapid Watershed Planning Handbook*, Center for Watershed Protection, 1998.

Ric Sorrell, *Computing Flood Discharges for Small Ungaged Watersheds*, Michigan Department of Environmental Quality, 2003.

Schueler and Holland, *The Practice of Watershed Protection*, Center for Watershed Protection, Article 28, 2000.

*Soil Survey of St. Clair County, Michigan,* United States Department of Agriculture, Soil Conservation Services, 1971.